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THE PATHOLOGY OF HERPES ZOSTER AND ITS BEARING ON SENSORY LOCALISATION.

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INTRODUCTION.

It would be useless to attempt a review of all the literature that has grown up around the subject of "Herpes Zoster," for from 1895 to the present time alone over seventy papers have been written on this subject, very few

of which have any bearing on the matter of the present communication.

Moreover, our work deals with herpes zoster from two aspects. Firstly, we have determined the pathological lesion which underlies this disease, and, secondly, we have attempted thereby to determine the cutaneous distribution of certain fibres that enter each posterior root ganglion. We shall, therefore, only allude to such communications as throw light on the pathological lesions in herpes zoster, or on the distribution of the fibres which enter the posterior root ganglia.

It was not until the appearance of von Bärensprung's classical paper (23) in 1861 that herpes zoster was stated to be definitely of nervous origin; and when von Bärensprung crowned his long series of admirably reported observations by a *post-mortem* examination (1), its association with a lesion of the posterior root ganglion was universally accepted. But as his conclusions in their passage from book to book have undergone modification, and as the position of the question he set himself to answer has been widened by our increased knowledge of the structure of the nervous system, it will be well to consider this first successful *post-mortem* examination more carefully. Moreover, we must remember that although von Bärensprung rightly placed the position of the lesion in the posterior root ganglion, he thought this structure stood in no connection with the fibres of the posterior root or peripheral nerve, but had special nerve-fibres of its own.

The eruption seems to have occupied the area we have called dorsal 7; for it ran in the form of a girdle over 2 inches in breadth between the 6th and the 9th ribs, passing the middle line behind for one or two lines at the level of the 5th to the 8th spines, to end beneath the xyphoid process. Death followed from tuberculosis forty days after the first appearance of the eruption.

The spinal cord and both anterior and posterior roots were stated to have been normal; but "Nachdem die Intervertebralkanäle geöffnet und die Intercostalnerven vom 5ten bis zum 9ten freigelegt waren fiel sogleich eine grössere Dicke und vermehrte Röthung des 6ten, 7ten und 8ten am

meisten aber des 7ten auf, die von einer Anschwellung des mit erweiterten stark geschlängelten Gefässen durchzogenen Neurilems vorzugsweise abzuhängen schien. Der Durchmesser des 7ten Nerve übertraf fast um die Hälfte den des 5ten und des 9ten Intercostalnerven . . . . Den 6ten und 8ten Nerv zeigten die nämliche Röthung und Anschwellung aber etwas weniger stark und auf eine kürzere Erstreckung als den des 7ten." He then states that he found the remains of extravasated blood in the ganglion, without mentioning to which of the three ganglia he alludes.

This case seems to have borne a close resemblance to No. 2 and No. 4 of our series, in both of which cases the swelling of the affected ganglion and nerve was obvious to the naked eye. Thus by little more than a naked-eye examination von Bärensprung was enabled to prove that the ganglion was affected in herpes zoster.

The next report of a *post-mortem* examination was made by Charcot and Cotard in 1865 (4). A woman suffering from cancer of the breast developed zoster over what appears to have been the 3rd and 4th cervical areas. At the autopsy secondary growths were found to have invaded many of the vertebræ, especially in the cervical region. The 4th cervical vertebra was found to be profoundly affected. The only change found in the nervous system consisted in an active injection of the capillaries of the ganglia and nerves, a "véritable neuritis" without concomitant alteration of the ganglion cells or nerve-tubes.

This case is so poorly reported that even from the point of view of a naked-eye examination it is valueless, either to elucidate the pathology or localisation of the lesion of herpes zoster. It would seem to have closely resembled case 14 of our series, where examination, even by the simple methods of that day, would have revealed marked changes in the affected ganglion.

The next case was reported by Weidner in 1870 (18). In a paper on three cases of zoster he reported two autopsies with negative results. This is not surprising, since in his first case, although the eruption lay over what we have called cervical 4, he only examined the cord ganglia and

nerves between cervical 7 and dorsal 2; and in his second case the patient died five years after the eruption.

In the same year E. Wagner (17) reported the result of an autopsy on a tuberculous patient who had developed an attack of zoster over the 9th and 10th ribs seven days before death. The six lower dorsal and the 1st and 2nd lumbar vertebræ were laid bare by tubercular caries, and the dura mater was lined with a thick layer of cheesy pus. Only the ganglia were examined microscopically, and the 9th, 10th, and 11th dorsal were said to have been affected. But it is obvious that an incomplete examination of so complicated a case could add little to the knowledge of either pathology or localisation.

In 1871, Oscar Wyss (19) reported a case of zoster of the whole first division of the trigeminal nerve, where death occurred seven days after the appearance of the eruption. The ophthalmic vein was thrombosed and the eye-muscles contained small abscesses, and the connective tissue of the eyeball was infiltrated with pus. From the point where the first or ophthalmic division leaves the Gasserian ganglion to enter the eyeball it was surrounded by extravasated blood. The second and third divisions were unaffected; but attached to the inner side of the Gasserian ganglion lay a red mass 1 cm. broad, apparently consisting of extravasated blood. Microscopically, there was an extravasation of blood into the inner aspect of the ganglion and into the first division of the trigeminal nerve. There is also said to have been "purulent inflammation" of the ganglion, pushing the ganglion cells apart.

In 1875, Sattler (16) also reported a case of herpes ophthalmicus, extremely well worked out according to the methods then known. A man of 85 was poisoned by carbonic oxide gas. Four days later neuralgia came on over the right half of the forehead, and in a few days the forehead, the side of the nose, and the eyelids, became covered with an eruption of herpes zoster. Death occurred fourteen days afterwards. The Gasserian ganglion was found to be infiltrated with small round cells, and there was marked destruction of the ganglion cells. The ophthalmic division

of the nerve was degenerated. The other two divisions were normal.

By this time it had come to be recognised that the ganglion was affected in cases of zoster, and in 1876 Kaposi (10) reported a case in which he arrived at a very odd result. A man of 54 died seven days after the appearance of an eruption that had the following distribution: "Auf der allgemeinen Decke des Unterleibes rechts über den Darmbeinkamm und mit diesem parallel laufend eine continuirliche Folge von Herpes-gruppen welche etwa 1½ bis etwa 1 Zoll vor und über der Symphyse sich erstrecken." The area affected seems to have corresponded with our dorsal 11. But he only examined the ganglia of dorsal 12 and lumbar 1 to 5, and states that hæmorrhages were present in the perigangliónic fat of dorsal 12, lumbar 1, 2 and 3, and that the protoplasm of lumbar 2, the most affected ganglion, was pale and retracted. In the light of our present knowledge it is impossible that these changes could have been associated directly with the eruption over the area he describes.

In his text-book Kaposi again alludes to this case, and states that he also examined a case of herpes frontalis and found hæmorrhage and destruction in the Gasserian ganglion. We have not, however, been able to find any further account of this second case, and the first case, though frequently quoted, is valueless as a contribution to the pathology of herpes zoster.

In 1879, Chaudelux (3) reported the case of a woman who died of phthisis many months after an attack of zoster. He says the remains of the eruption lay over the 2nd and 3rd intercostal spaces on the left side, but gives no further details of its distribution. The 2nd and 3rd dorsal ganglia of the left side are said to have been double the normal size, and certain zones in these ganglia were completely transformed, ganglion cells and nerve-tubes were destroyed, and their place taken by dense connective tissue. From the figure he gives he evidently saw the condition figured by us on plate 1, fig. 2B. The spinal cord was destroyed in extraction, and the nerves, having been hardened in alcohol, gave no positive result.

In 1881, Lesser (12) published the first two satisfactory *post-mortem* examinations of cases of zoster of the trunk, and followed up his first communication by a second in 1883 (13), in which he reported a third case. In the first of these three cases the eruption lay over the right side of the neck, bounded in front and behind by the middle line, above by the lower jaw, and below by a line passing round the shoulder roughly to join the spine of the 2nd dorsal vertebra behind, with the third costal cartilage in front. This lower border dipped in front to occupy the extreme upper part of the anterior surface of the right arm. Death occurred twenty-six days after the eruption first appeared. The 4th cervical ganglion of the right side contained a focus visible to the naked eye, and situated on that side of the ganglion opposed to the anterior root. Microscopically, this focus consisted of a mass of cells surrounding what appeared to be the remains of a hæmorrhage. The remaining ganglia, the posterior roots, the nerves, and the spinal cord were stated to be normal; but at that date no method existed by which the acute degenerative changes that probably existed could have been demonstrated.

In Lesser's second case the eruption appears to have occupied the area that we should call dorsal 8, and death took place about nine days after its first appearance. To the naked eye the 8th dorsal ganglion was very red, but not swollen. On microscopical examination this reddened area was seen to consist of a hæmorrhage containing broken-down ganglion cells, and surrounded by a mass of inflammatory tissue. The case seems closely to have resembled Nos. 2, 4, and 5 of our series. Lesser thought that there was a similar though less pronounced change in the 9th dorsal ganglion, but he carefully states that there was no hæmorrhage or breaking-down of nerve elements, and our experience leads us to suspect that he was mislead by the hyperæmia not infrequently present in normal ganglia; for he was evidently unwilling to believe that one ganglion could supply the whole of the area occupied by the eruption. The other ganglia, peripheral nerves, and spinal cord showed no change. Admirable figures accompany this paper, which is the first serious con-

tribution to the pathology and localisation of zoster of the trunk.

Lesser's third case (13) died three weeks after an eruption that lay over the mamma and occupied the area we have called dorsal 5. On microscopical examination the 5th dorsal ganglion was found to be markedly altered. The nervous elements of the upper half of the ganglion were replaced by connective tissue, and the sheath of the ganglion over this area was thickened. The peripheral nerve of this ganglion also showed changes, for the normal fibres were in places widely separated by fields of granular tissue. He states that the 4th ganglion also was altered, but that the 4th nerve was normal. As, however, he gives no figures in this paper, it is difficult to gather the extent of these changes, and he admits that the 4th ganglion was not so carefully examined as the 5th.

In 1883, Pitres and Vaillard (15) reported the *post-mortem* on a curious case. After mentioning a number of cases in which they had examined the nerves in the neighbourhood of bed-sores, they mention a case in which there were scars of zoster in the 6th intercostal space on the right side, and an eruption that they thought was zoster in the 11th intercostal space of the same side. On microscopical examination they state that in the 6th dorsal ganglion nerve-fibres were destroyed but the cells were perfect, that there was parenchymatous degeneration and some sclerosis of the 6th dorsal peripheral nerve and degeneration of the posterior roots of the 6th dorsal. They also state that the 11th dorsal peripheral nerve was degenerated and sclerosed, but that the ganglion and roots were normal. The cord was everywhere normal. In the light of subsequent experience it would seem that the scars in the 6th intercostal space were probably due to an old zoster, but that the eruption in the 11th space cannot be classed under the heading of true zoster. However, the case is so poorly reported that it can add but little to our knowledge.

In 1884, Curschmann and Eisenlohr (5) published two cases in which an eruption of zoster was followed by the development of small nodular swellings on the peripheral

nerves. In the first case several of these swellings were removed by operation. Microscopically they were found to consist of healthy nerve-fibres surrounded by small hæmorrhages, exudation of inflammatory cells and engorged cappillaries, in fact, a condition of "perineuritis acuta nodosa." This case died a year and nine months afterwards, and they found no change in nerves, ganglia, or cervical cord.

They also report a third case in which zoster appeared two days before death over the 11th rib and last intercostal space. On *post-mortem* examination the back muscles on the same side as the eruption were found to be infiltrated with blood, and through this infiltration passed the branches of the 10th and 11th dorsal nerves. The nerve-fibres in these branches were, however, unaltered, and the 10th, 11th and 12th dorsal ganglia and the dorsal and lumbar cord were normal. But it is not improbable that these observers, like Pitres and Vaillard, were misled by their idea that zoster was due to changes in the peripheral nerves. Thus the fact that the anterior divisions of the 10th and 11th dorsal nerves passed through the broken-down muscles, caused them to imagine that these nerves must have been the seat of the lesion in spite of the fact that their peripheral branches do not supply the area over which the eruption lay (*vide* our plate 17). Probably the seat of the lesion in this case was the 9th dorsal ganglion, which they neglected to examine.

In 1884, Dubler (7) published the results of an examination of two cases. Of these we will consider the second and more straightforward case first. The distribution of the eruption, which occurred 103 days before death, was as follows:—"Rechts über den unteren Rippen und über der unteren Bauchgegend eine von oben hinten nach vorn unten verlaufende 5 cm. breite gürtelförmige Hautpartie . . . . Diese Hautveränderung beginnt hinten an der Wirbelsaüle, reicht vorn bis zur Mittellinie wo sie 4 Querfinger oberhalb der Symphyse endet. Seitlich bleibt sie 3 Querfinger von der Spina Anterior Superior entfernt."

Microscopically the spinal cord was normal. The 9th dorsal ganglion showed interstitial changes, degeneration of nerve-bundles and small pin-point hæmorrhages and dots.

The 8th and 10th dorsal ganglia were normal. The 9th intercostal nerve and 9th dorsal roots were degenerated, and there was a small amount of degeneration in the 10th intercostal nerve.

Dubler's first case is less clear owing to the fact that the patient had tubercular necrosis of several ribs. The eruption seems to have occupied the area we have called the 8th dorsal, and the patient died 144 days after its first appearance. On the 7th, 8th and 9th ribs were caseous masses, due to necrosis of the bone. The 6th, 7th, 8th and 9th intercostal nerves passed through these swellings. A few nerve-fibres were degenerated in the anterior division of the 7th intercostal nerve; there was marked degeneration in the posterior and anterior primary divisions of the 8th intercostal nerve, and slighter degeneration in the anterior division of the 9th intercostal. Ganglia, cord and posterior roots were said to be normal at the level of the 6th, 7th, 8th and 9th dorsal.

In 1887, Leudet (14) published a somewhat superficial paper in which he mentions a case of herpes frontalis where he found an old inflammatory process in the frontal nerve, and a degenerative condition of the Gasserian ganglion.

Thus up till the time we began to investigate the pathology of herpes zoster there had been two well reported autopsies on cases of zoster ophthalmicus [Sattler (16), Wyss (19)], and five satisfactory reports on zoster of the trunk [Lesser, three excellent cases (12 and 13), Chandelux, one fairly reported case (3), Dubler, one excellently reported case (7)].

To these we now add twenty-one cases at all stages after the eruption.

Part I.—The Pathology of Zoster.

Chapter 1.—*Changes in the ganglion of the Posterior Root.*

If the patient has died with the eruption still out upon his skin the affected ganglion will be found to be in a condition of profound inflammation. The interstitial tissue will be crowded with small round cells which stain deeply with

methylene blue and other nuclear dyes. Here and there these inflammatory cells may be closely massed into clumps, and such foci may be scattered round the periphery and in the central tissue of the ganglion.

If these foci of inflammatory cells are examined in serial sections they will occasionally be found to be situated around extravasated blood which has undergone more or less change according to the length of time at which death has occurred after the first appearance of the eruption.

But not infrequently the hæmorrhage is of much greater extent and produces changes that are noticeable without the aid of the microscope.

In Case 1, where the patient died only three days after the outbreak of the eruption, the whole centre of the ganglion is ploughed up by a large hæmorrhage, and this condition produced an alteration in consistence that attracted attention as soon as the ganglion was fixed. In both Case 2 and Case 5 a swollen condition of the peripheral nerve close to the ganglion was noticeable at the autopsy. Thus the intensity of the inflammation in the interstitial tissue of the ganglion is such that blood is extravasated, it may be only as a microscopic hæmorrhage or it may be in sufficient quantity to produce an actual swelling of the affected part.

The inflammation and hæmorrhage are situated in the dorsal aspect of the ganglion, *i.e.*, in that portion opposed to the anterior root. The ganglionic substance may be destroyed to a greater or less extent, but if hæmorrhage has occurred at all we have always found it in the dorsal half of the ganglion.

In the centre of these hæmorrhagic foci the ganglion cells are absolutely destroyed. But in the surrounding zone of small round cells the remains of ganglion cells can be generally seen in the form of pale masses, which do not stain with methylene blue, but stain strongly with safranin. Further, towards the periphery of these inflammatory foci some ganglion cells usually appear, when stained by Nissl's method, as dark blue lumps without any differentiation of structure.

In some cases the nuclei of the ganglion cells seem

swollen and, by Nissl's method, stain of a uniform blue colour, which is so intense that no nucleolus and no trace of the normal reticular arrangement of the nucleus is recognisable. Such nuclei retain their colour so firmly that they are still well stained when all other structures have given up the dye. In van Gieson preparations these nuclei appear of a dark brown colour, and with Ehrlich's hæmatoxylin they assume a uniform deep purple.

The substance of the bodies of these cells has a uniform blurred appearance, entirely devoid of definite structure, and the chromophilic particles of Nissl are completely obscured.

Such are the changes found in the cells of the posterior root ganglion, starting from within the hæmorrhagic centre of an inflammatory focus and working outwards towards the periphery. The extent to which the cells show one or other of these changes varies in different cases.

But in the affected ganglia many cells are usually seen which show no noticeable alteration, and in no instance of spontaneous zoster have we been able to see those minor chromatolytic changes that are so commonly present in degenerative diseases of the nervous system. The inflamed ganglia show no ganglion cells with extruded or excentric nuclei with vacuolation or partial disappearance of Nissl's particles. Thus, where such conditions were present in addition to the herpetic lesion as in No. 15 (a case of fractured spine), or in No. 14 (a case of malignant disease), the contrast to the conditions usually seen in herpetic ganglia was most instructive.

Over that portion of the ganglion which is inflamed the sheath generally shows similar changes. The vessels are engorged and occasionally blood may be extravasated, but in all cases where the inflammation in the ganglion was severe the sheath was invaded by multitudes of small round deeply staining cells.

On account of the severity of these inflammatory changes in the ganglion it is difficult, even in the serial sections at our disposal, to select any individual artery to an interference with which the focal lesion can be ascribed. But in one acute case (No. 4) an arterial branch, entering at the distal

pole of the ganglion and proceeding towards the lesion, differed from similar vessels in the normal part of the ganglion in that an abundance of extruded leucocytes occurred along its course. With lapse of time the identification of such an artery becomes increasingly impossible.

If not severe, the inflammation may pass away and leave no recognisable change behind in the ganglion. In Case 20, where the eruption was scanty and the inflammation of the skin not severe, no changes could be found 139 days after it first appeared.

But the greater the severity of the eruption, and the profounder the scarring it leaves behind it, the more certainly will permanent changes be found in the posterior root ganglion. Thus out of thirteen cases that were examined between 57 and 790 days after the eruption appeared, eleven showed obvious microscopical evidence of a past inflammation in the posterior root ganglion.

As soon as the virulence of the inflammation has expended itself absorption begins. Round cells are seen within the capsule of each dead ganglion-cell, apparently eroding it. In one case (No. 15) it seemed as if some of these scavenger cells might have been derived from the cells of the capsule of the ganglion cell itself.

The effused blood undergoes retrogressive changes, and if not completely removed remains only as a mass of brownish granular deposit in the centre of the scar tissue. (Cases 8, 18 and 19). For ultimately the focus of inflammation becomes converted into fibrous tissue, and the density and extent of this scar depends on the severity and extent of the original inflammation. Usually the final result is a scar occupying from one-sixth to a half of the ganglion. Within this area all ganglion cells and nerve-fibres are destroyed, and no structure remains to show where they once existed. But in several cases a few healthy ganglion cells, and still more often a few healthy nerve-fibres, can be seen scattered in the scar tissue.

Over this scar in the ganglionic tissue, the sheath is thickened and altered in appearance (plate 1, fig. 2B, plate 6, fig. 2). The sheath of a normal ganglion is made up of

crescentric layers of fibrous tissue separated from one another by lymph spaces, and presents on section somewhat the appearance of the sheath of an onion. Over the sclerosed patch in the ganglion this appearance is lost, and the sheath becomes converted into an almost homogeneous mass of dense fibrous tissue. The sheath may become three times the thickness of the normal, and present a curious non-lamellated appearance, in marked contrast to the normal wavy appearance of the remainder of the sheath.

The sclerotic changes in the ganglion and its sheath are well shown on plate 1, fig. 2B, which represents the affected ganglion in a case that died 153 days after the eruption came out. The affected portion of the ganglion stains a brilliant red colour with van Gieson's picro-hæmatoxylin method in marked contrast to the purple red colour of the ganglion of the opposite side (plate 1, fig. 2A), which contained its normal complement of nerve-cells and fibres.

Now such a condition obviously corresponds to what might have been expected to result from an acute condition, such as that shown on plate 1, fig. 1.

Thus, in conclusion, the acute changes found in the ganglion in a case of herpes zoster consist of an (1) Extremely acute inflammation with the exudation of small round deeply-staining cells; (2) Extravasation of blood; (3) destruction of ganglion cells and fibres; (4) inflammation of the sheath of the ganglion.

If severe such a condition ultimately leaves a scar in that part of the ganglion affected and leads to thickening of the sheath above the affected area. On the other hand if the eruption has not been severe all traces of the inflammation present in the acute stage may pass away, leaving the ganglion apparently normal.

Chapter 2.—Changes in the Posterior Nerve-Roots.

It is obvious that with so considerable a destruction in the posterior root ganglion secondary degeneration must

occur in the posterior nerve-root to an equivalent extent. In fact we are here dealing with a lesion as strictly localised as that of any experiment.

Moreover, as death occurred at the most varied intervals after the outbreak of the disease, we had the opportunity of learning the length of time that is required for a nerve-root to degenerate after partial destruction of the ganglion.

In Case 2 death occurred eight days after the first appearance of the eruption, and here no change could be found in the posterior roots on careful examination by Marchi's osmium bichromate method.

Thirteen days after the eruption first appeared in Case 4, profound degeneration was present in the posterior roots, and it is probable that this degeneration begins to make its appearance ten days after the appearance of the eruption. For although the posterior roots could not be examined in Case 3, the degeneration in the root after it had entered the spinal cord was so profound that it was probably degenerated in its extraspinal course. This case died on the eleventh day after the eruption began to appear.

This degeneration is of the usual acute type, and by Marchi's method is seen to consist of a profound disintegration of the myelin sheath. The broken-down sheath stains deep black, and black dots can be seen lying in rows like broken beads within the primitive sheath (plate 16, fig. 1).

In the earlier cases fibres are also seen in which the normal cylinder of medullated substance has been replaced by collections of black or dark brown globules. The groundwork of the medullary sheath of these fibres stains of a pale gray colour, and in it are distributed crowds of coarse refractile dark brown granules, which occasionally occur in lines or fusiform clumps. These fibres, swollen in some places and contracted in others, have a wavy outline.

This acute change seems to have reached its height by about the fifteenth day after the appearance of the eruption. The products of acute degeneration are then gradually cleared away, and if the destruction has been profound, fibrous tissue takes the place of the destroyed nerve-fibres. If, however, the degeneration has not been

of considerable extent, this disappearance of the products of acute destruction may produce no recognisable change in the posterior root.

However, the extent of the acute lesion is usually sufficiently great to cause a noticeable increase of connective tissue in one or more bundles of the posterior root.

Thus fifty-seven days after the eruption this secondary sclerosis was already quite evident (Case 6), but one hundred and fifty-three days after the eruption (Case 9) the last remains of the products of acute degeneration could still be seen amongst the secondary fibrous tissue. After two hundred and seventy-two days (Case 10), all signs of acute degeneration had disappeared, but the sclerosis was well marked, more than one half the posterior root being replaced by fibrous tissue.

If the lesion has been severe the fibrous tissue becomes less vascular and finally settles down into permanent scar tissue, clearly visible seven hundred and ninety days after the eruption (Case 13).

Thus the changes we have found in the posterior nerve-root corresponded to the results that might have been expected from the lesion of the ganglion. They consisted of an acute degeneration followed by a greater or less amount of secondary sclerosis according to the severity of the acute destruction.

The anterior root was in all cases normal.

Chapter 3.—*Changes in the Peripheral Nerves.*

As might have been expected a lesion of the ganglion such as we have described produces marked secondary degenerative changes in the fibres that enter the posterior root ganglion. In the mixed trunks of the peripheral nerve close to the ganglion these acutely degenerated fibres stand out clearly (when stained by Marchi's method), against the normal fibres of the anterior root. The number of these degenerated fibres varies considerably with the severity of the ganglionic lesion. It is best studied in the simpler trunks of the mid-dorsal region rather than in the more com-

plicated anastomoses of the cervical and upper lumbar regions.

Eight days after the eruption (Case 2) no acute degeneration could be found in the peripheral nerves in connection with the affected ganglion, but thirteen days after (Case 4) degeneration was present to a marked degree.

By Marchi's method the degenerated fibres show the same breaking up of the myelin sheath and irregularity of outline already described when considering the changes in the posterior roots, appearances identical with those seen after an experimental lesion.

Both posterior primary and anterior primary divisions are markedly affected, but the number of degenerated fibres in the posterior primary division always appears to be greater, probably owing to the almost entirely afferent nature of this branch in the dorsal region.

This degeneration can be traced right back to the fine twigs which pass upwards into the skin to supply the area over which the eruption is distributed.

With time the products of degeneration are removed from the peripheral nerve, and if the ganglionic lesion is not severe it may be impossible to be certain of any abnormality in the peripheral nerves. On the other hand, if the lesion has been a severe one the nerve-fibres that have degenerated are replaced by fibrous tissue and whole bundles of the nerve may be sclerosed (plate 16, fig. 3).

This sclerosis was evident in Case 18 thirty days after the eruption but, on the other hand, Marchi's method still showed some remains of acutely degenerated fibres 100 days after the eruption alongside the sclerosis (Case 8). The sclerotic change, once established, is permanent, and was visible 790 days after the eruption (Case 13).

Thus, in the peripheral nerves degeneration seems to appear, to disappear and to be replaced by sclerotic changes at the same periods after the initial lesion in the ganglion, as was the case with the posterior roots.

So far we have treated the peripheral nerves as if they were not affected by any condition other than that of degeneration secondary to the ganglionic lesion. But in

two of our cases hæmorrhage and inflammation occurred not only in the ganglion, but in the peripheral nerve in connection with it. In Case 2 this hæmorrhage extended for about 1 cm. down the course of the combined peripheral trunk, which was swollen until its diameter was that of a normal ganglion (*vide* also Case 4, plate 8, figs. 3 and 4).

Chapter 4.—*Degeneration in the Spinal Cord.*

When a posterior root ganglion is excised, or a posterior root divided experimentally, acute degeneration takes place in those fibres which, entering the spinal cord by that root, run upwards in the posterior columns. Thus it is not surprising that such lesions of the ganglion as we have described in the previous section should be attended by acute degeneration of the root-fibres in the posterior columns of the spinal cord.

This degeneration probably appears about the ninth or tenth day after the eruption. For in Case 2, although the ganglionic lesion was an extremely severe one, no degeneration had made its appearance in the spinal cord eight days after the eruption. On the other hand, in Case 3 acute degeneration was present to a marked degree eleven days after the first appearance of the eruption. Thirteen (Case 4) and fourteen days (Case 5) after the eruption first appeared this degeneration was extremely well marked and appeared to have almost reached its full development.

When dealing with the similar degeneration in the fibres of the posterior roots we drew attention to the rapidity with which the products of this acute degeneration were removed and replaced by secondary fibrous tissue. In the spinal cord, on the other hand, the products of acute degeneration are removed much more slowly. Thus, fifty-seven days after the eruption in Case 6, the products of degeneration in the posterior roots showed signs of absorption, and these roots were already considerably sclerosed. But the degeneration in the spinal cord was extremely well marked and the degenerative material that stains black with osmic acid showed no signs of absorption. In the same way in Case 18

the products of degeneration in the root of the Gasserian ganglion showed marked absorption, with the deposition of secondary fibrous tissue, thirty days only after the outbreak of the eruption. Yet the degeneration in the medullary or descending root of the 5th nerve was profoundly marked and showed no signs of absorption.

One hundred and fifty-three days after the eruption (Case 9) the acute degeneration in the spinal cord was still profoundly marked, but in 272 days it had disappeared.

Unfortunately we possess no case between 153 and 272 days after the eruption, and cannot therefore say the earliest date at which the acute degeneration is cleared away; for in Case 9 the degeneration showed no signs of diminution, and in Case 10 it had gone. But in Case 19, where the eruption lay over the ophthalmic division of the trigeminal, no signs of acute degeneration could be found in the pons or medulla 190 days after the eruption first appeared. This case is, however, open to the objection that the scarring was slight and the lesion in the ganglion not severe.

When the degeneration is cleared away from the spinal cord it leaves no perceptible sclerosis behind it, probably owing to the relatively small number of fibres destroyed. Thus, 272 (Case 10), 481 (Case 11), 515 (Case 12), and 790 (Case 13) days after the eruption no abnormal changes of any kind could be found in the spinal cord that could be referred to the herpetic lesion.

The course followed by the degenerated fibres in the spinal cord is exactly that which might have been expected from the known results of experimental division of posterior roots. Where the pencils of the degenerated posterior root penetrate the spinal cord there is a brief length where there is no marked blackening of the fibres. For, as Obersteiner has shown, the medullary envelope of each fibre is here reduced to small proportions. But centralwards of this point degenerated fibres can be seen in a transverse section running for a short distance along the inner margin of the tip of the posterior cornu. This field of degeneration hugs the posterior horn, and the degenerated fibres are most numerous opposite the substantia gelatinosa Rolandi.

Thence the field tapers inwards, to end about two-thirds of the way along the posterior horn.

In the centre of the gray substance of the posterior horn, immediately ventral to the substantia gelatinosa, a few degenerated fibres are usually seen cut transversely and apparently of small calibre.

In longitudinal sections pencils of degenerated fibres can be seen streaming inwards to join a mass of degeneration that ascends the cord in the root zone of the posterior column (plate 15, figs. 1 and 2). This stream of degeneration contains fibres of both small and large calibre.

One segment below the entry of the diseased root a few fibres can be seen cut transversely and scattered irregularly in the root zone close to the posterior horn. These descending collaterals are fewer in number than we expected, so few in fact that they must be looked for carefully in order to be seen at all. Two segments below the entry of the diseased root we have also seen a few scattered degenerated fibres, but sometimes we have not been able to be certain of any degenerated fibres at this level.

Tracing the field of degeneration upwards we find that one segment above the entry of the degenerated root the blackened fibres lie entirely in the root-zone of the posterior column, and the posterior horn is clear of degeneration. The subsequent destination of the field of degenerated fibres varies according to the position of the affected ganglion.

In Case 7 where the 2nd dorsal ganglion was affected and the eruption lay over the inner aspect of the arm, the degenerated fibres in the spinal cord can be clearly followed up to the inner portion of the nucleus cuneatus in the medulla. At the level of the 1st dorsal root they lie on the inner aspect of and apparently in direct contact with the posterior horn. At the level of the 8th cervical they are separated from the horn by a thin band of normal fibres. At the level of the 6th cervical they form a tiny triangle with its base on the external (dorsal) surface of the postero-external column and its inner side in close opposition to the inter-columnar septum. In this position they can be followed up the spinal cord, gradually decreasing in

number, but a remnant can be clearly traced into the inner portion of the nucleus of the funiculus cuneatus (plate 10, fig. 1).

We have examined no case in which the eruption was situated entirely over the leg. But in two of our cases (No. 4 and No. 8) the eruption lay over the area of the 12th dorsal, the highest to send branches to the front of the thigh. Fortunately one of these cases (No. 4) is an early (13 days), the other (No. 8) a late (100 days) example (plate 12, figs. 1 and 2).

At the level of the 10th dorsal root two segments above the entry of the diseased fibres, the degeneration forms a strip separated by a distinct interval from the posterior horn, reaching internally to a point almost opposite Clarke's column. In the central portion of this strip the fibres are more closely packed than in the outer portion. Higher up, at the level of dorsal 9, the degenerated fibres have shifted further inwards towards the middle line and are mainly situated in the inner half of the postero-external column. This strip begins in the neighbourhood of Clarke's column and extends as before to the periphery, but the degenerated fibres are still more closely packed in that part nearer the central portion of the cord. Two segments higher (dorsal 7) a small number of the fibres of this strip lie in the outer portion of the postero-internal column (Goll). Thus as they ascend the cord the degenerated fibres are gradually pushed inwards, diminishing in number on their upward journey. At the level of dorsal 6 (Case 8), 150 degenerated fibres were counted as opposed to 210 at the entry of the affected root. At the level of dorsal 3 the strip of degenerated fibres lies on the inner side of the boundary separating the postero-internal from the postero-external columns. At the level of cervical 7 the central half of this strip lies against the postero-median septum, whilst that half nearer the peripheral portion of the cord lies along the outer border of the postero-external column. In Case 8 the degeneration cannot be followed higher than this level, but in Case 4 a few degenerated fibres can be seen two segments higher (cervical 5).

Thus in a suitable case, where the area of the eruption

extends on to the arm, the degenerated fibres can be followed in the cord from the root zone to the postero-external column, and by this path up to the nucleus of this column, the nucleus cuneatus. Where, on the other hand, the eruption lies on the leg, the field of degeneration passes into the postero-internal column, and one half of the field finally lies against the posterior median septum. As the two cases we have examined were both instances of dorsal 12, the highest area that touches the leg, the more peripheral portion of the degenerated field is seen to lie at the juncture of the postero-internal and postero-external columns.

So far the degeneration we have observed in the spinal cord, secondary to the herpetic lesion of the ganglion, exactly confirms the results of experiments on animals. For the postero-internal column (Goll) in the cervical region, has been shown experimentally to consist almost exclusively of fibres from the leg, the postero-internal (Burdach) of fibres from the arm. But when the lesion lies in a ganglion of the dorsal region, between the 3rd and the 11th dorsal, this secondary degeneration in the spinal cord follows a somewhat different course.

This difference in behaviour is exemplified in Case 9. The degenerated fibres are seen to enter at the 7th dorsal root, and one segment above occupy the root zone adjacent to the posterior horn. They diminish in number on their upward course, and come more towards the periphery of the spinal cord, to disappear entirely at the level of the 1st dorsal. In the same way the degenerated fibres that enter at the 6th dorsal root in Case 3, disappear at the level of the 1st dorsal.

Thus, whereas a lesion at the level of the 12th dorsal will produce a degeneration which ascends fourteen segments, a lesion at the level of the 7th dorsal will cause degeneration, which ascends only five segments. This cannot be due to the length of time that has elapsed, for in thirteen days (Case 4) a lesion of the 12th dorsal ganglion had caused degeneration that ascended to the level of the 5th cervical, whilst in fourteen days (Case 5) a lesion of the

6th dorsal ganglion produced degeneration that ceased at the level of the 1st dorsal.

The following table illustrates this difference between the behaviour of the root fibres in the dorsal as opposed to the limb areas :—

	Lesion.	Highest Level of Secondary Degeneration.	Number of Segments.	Duration.
Case 7 ..	Dorsal 2	Nucleus Cuneatus ..	10	96 days.
Case 3 ..	Dorsal 6	Dorsal 1	6	14 days.
Case 9 ..	Dorsal 7	Dorsal 1	7	153 days.
Case 5 ..	Dorsal 11	Dorsal 6	6	14 days.
Case 8 ..	Dorsal 12	Cervical 7	14	100 days.
Case 4 ..	Dorsal 12	Cervical 5	16	13 days.

This difference of behaviour shows that the posterior roots in the dorsal region containing as they do afferent fibres from the trunk, consist mainly of short fibres which do not form a part of either the postero-internal or the postero-external columns in the cervical region of the spinal cord, whilst the long fibres that form these columns come almost exclusively from the leg and the arm respectively.

This fact with regard to the constitution of the roots in the dorsal region seems to have escaped experimenters, and is of interest in conjunction with the observations of Münzer (36), who found that division of the postero-internal and postero-external columns in the cord caused no loss of conduction of pain stimuli, but that destruction of the root zones when the postero-external and internal columns remained intact, abolished the conduction of painful impressions.

Chapter 5.—Zoster of the Trigeminal.

We pointed out in the Introduction that the first satisfactory report on the *post-mortem* appearances in zoster

was given by Sattler (16) on a case of so called herpes ophthalmicus. He found an inflammatory lesion with hæmorrhages destroying both the nerve-cells and fibres of the Gasserian ganglion.

We can confirm his statement from the examination of two cases of zoster within the territory of the trigeminal nerve.

One of our earliest cases (Case 19) was a typical supra-orbital zoster, covering the whole of the first or ophthalmic division of the trigeminal nerve, excepting only that the eruption did not extend to the side of the nose. Death occurred 190 days afterwards, and the Gasserian ganglion showed what appeared to be the remains of an old hæmorrhage with some destruction of nerve-cells in that portion corresponding to the first division.

The root bundles of the affected ganglion showed an appearance that made it probable that a few of them were sclerosed, but there was no acute degeneration in any part of the central nervous system referable to the lesion in the Gasserian ganglion.

In Case 18 death took place thirty days after the outbreak of the eruption, and we found here all the changes, both ganglionic and degenerative, which we have described in cases of zoster affecting the body. In this case an eruption of the zoster type lay over the right lower jaw, limited absolutely to one side of the face. Fig. 18 shows how completely this eruption followed the anatomical distribution of the third or maxillary division of the trigeminal nerve. At death a few lightly scabbed scars were still present over the temporal portion of this trunk.

A comprehension of the position of the ganglionic lesion in this case will be facilitated by considering the Gasserian ganglion as a triangle, from the inner angle of which the greater part of the central root-fibres come off. At the preaxial angle of this triangle the first or ophthalmic division, and at the postaxial angle the third or maxillary division, enters the ganglion. A focus of destruction is seen (plate 9), running almost parallel with the postaxial side of the triangle directly dorsal of the position of the

motor root; that is to say, it occupied that portion of the ganglion which stands in direct relation with the maxillary branch.

This focus is roughly oval in transverse section. Its greatest transverse diameter is 1·275 mm.; its greatest vertical diameter 0·765 mm. It appears to be made up of a large central nucleus containing brown material, obviously the broken-down remains of a hæmorrhage and the *débris* of destroyed nerve-cells. This is surrounded by an area abundantly occupied by small round cells and enveloping this area, extending up to the pia on the free surface; and for some distance into the ganglionic substance is a wider zone densely infiltrated with small round cells in which remains only of nerve-cells and nerve-fibres can be seen. The remainder of the ganglion is healthy.

Thus we here find an exact reproduction of the familiar lesion in the posterior root ganglion, and just as the sheath of the spinal ganglion tended to become implicated in the lesion, so over this focus in the Gasserian ganglion the pia shows signs of thickening and infiltration.

Secondary to this lesion there is some degeneration in the root of the fifth nerve. It is principally confined to three small fasciculi lying at the periphery of the transverse section opposite to the motor root. But although the lesion is only thirty days old much of the black material of the broken-down medullary sheaths is already cleared away and sclerotic changes are well advanced; but in the pons and medulla the degenerated fibres still stain by Marchi's method, just as if they were freshly degenerated. Thus here, again, the intramedullary and extramedullary portions of the central projection of a neuron behave exactly as in the spinal cord, and the products of degeneration are removed much more rapidly from the root than from the central nervous system.

In the pons the so-called "descending" or cerebral root is completely free from degeneration, thus confirming the usually accepted view that this is the central portion of the motor root.

The so-called "ascending" or spinal root shows acute

degenerative changes. At the point of entry into the pons a few scattered degenerated fibres are seen in all the bundles of the root, but in the outer portion 2-3 fasciculi are gravely affected. These fibres can be followed into the pons, and appear, when close up to the nucleus, to curve abruptly downwards external and ventral to the nucleus (plate 13, fig. 3).

More caudalwards, as soon as the sensory bundle has formed into its pear-shaped area, the degenerated fibres are seen to lie almost entirely in the upper two-thirds of this pear-shaped tract. The lower one-third is practically free from degeneration (plate 13, fig. 6).

No fibres cross to the opposite side. At the level of the seventh nucleus the fibres are cut transversely instead of somewhat obliquely, and they lie almost entirely in the upper two-thirds of the pear-shaped field.

Opposite the great olive the degenerated fibres are less numerous, but are still situated in the upper two-thirds of the field.

Opposite the main decussation of the fillet the root lies between the dorsal half of the substantia gelatinosa Rolandi and the surface. Here the degenerated fibres again lie in the dorsal portion of the field and the ventral portion is practically free from degeneration.

Opposite the 1st cervical root the degeneration is indistinct, but in the most dorsal portion of the substantia gelatinosa an obvious collection of black dots is seen not represented on the opposite side.

Thus we can state for certain that in man the third division of the trigeminal is connected with cells in the Gasserian ganglion which send fibres centralwards to lie in the so-called "ascending" or spinal root. They occupy the dorsal two-thirds of this bundle almost exclusively.

Now the second division of the trigeminal is closely allied to the third division in nature and function in that both supply structures derived from the arches that enclose the first gill slit [*vide* Head (28), p. 476]. It is therefore probable that the remaining undegenerated fibres of the spinal root of the trigeminal belong to the second division.

On the other hand, the first or ophthalmic division stands apart from the other two branches in its curious participation in visceral pain referred from organs of the thorax and abdomen. Thus it is possible that the central projection of the cells which give rise to this division may end around the upper sensory nucleus of the trigeminal nerve. For in the case we have just described the fibres which pass to end around this nucleus do not show any obvious signs of degeneration.

In conclusion, we may state that zoster of the branches of the trigeminal is associated with a similar lesion in the Gasserian ganglion to that found in the posterior root ganglia in cases of zoster of the trunk and limbs.

This lesion causes secondary degeneration in the sensory root of the Gasserian ganglion both in its extra- and intramedullary course.

Chapter 6.—Zoster secondary to implication of the Ganglion in General Disease Processes.

In all the cases that we have so far considered, zoster has arisen as a primary manifestation. Some agent of the nature of which we are ignorant chooses the substance of the posterior root ganglion for its selective activity, producing profound inflammatory changes. These destructive changes in the ganglion produce irritation of its nerve elements, and to this irritation is due the eruption on the skin.

Now it is interesting to find that acute inflammation of a posterior root ganglion, due to its implication in some local inflammatory process, can apparently produce an herpetic eruption indistinguishable from an eruption which arises as manifestation of the acute specific disease.

It is well known that when the secondary deposits of malignant disease attack the spinal column the pain produced becomes intense. This is due to the implication of the central portion of the peripheral nerve-trunks and the nerve-roots in the new growth. It is, however, less a matter of common knowledge that an eruption indistinguishable

from that of zoster may also make its appearance. Charcot and Cotard (4), gave a very insufficient report of such a case in 1865, but we can find but one other paper dealing with this subject [Risel (38)].

In Case 14 of our series, a man of 40 suffered from lympho-sarcoma that affected all the large groups of lymphatic glands. Seventeen days before death he developed a severe herpetic eruption over the 4th dorsal area. On *post-mortem* examination the mass of glands in the posterior mediastinum was profoundly affected by new growth and this growth had invaded the spine, passing inwards along the great peripheral nerve trunks into the foramina. The upper seven dorsal foramina on the right side, the side of the eruption, all contained new growths, which surrounded the ganglion and posterior roots. In most cases the posterior roots had suffered and showed degenerative changes, as might have been expected from their delicate structure; but only one of the ganglia showed any inflammatory change. In most cases the tough sheath had resisted invasion by the new growth that could be seen in the periganglionic connective tissue. However, it was noticed at the *post-mortem* examination that the 4th dorsal ganglion of the right side was entirely concealed in the mass of new growth that filled the foramen in which it lay, and the contents of the foramen were therefore removed in their entirety. When the mass so obtained was hardened and cut, it was at once obvious that the ganglion lay in the centre like the stone of a plum. Microscopically the whole ganglion is infiltrated with small round cells, which stain profoundly with methylene blue (Nissl's method). So deeply do these cells take the dye that the whole ganglion may be decolourised and yet they remain overstained. Where these cells are most thickly crowded together remains of ganglion cells can be seen as white or greenish blue discs with an unstained nucleus and quite undifferentiated. These cells take the counter-stain erythrosin readily, and appear as pink undifferentiated bodies in the centre of a mass of small round deep blue inflammatory cells. Where the inflammation is less intense the ganglion

cells either stain as uniform blue masses or they show marked chromatolytic changes. The body of such cells presents a granular appearance, Nissl's particles have disappeared and large light patches may be present in the protoplasm when stained by Nissl's methylene blue method, The nucleus is excentric and appears in some cases to have been extruded. In fact, the changes in these cells are those seen in any cell containing portions of the nervous system from which the blood supply has been cut off [Sarbó (39). Mott (34)].

Thus the 4th dorsal ganglion in this case, lying in the centre of a mass of new growth, showed firstly a profound inflammatory change in the interstitial tissue, and secondly changes in the ganglion cells, which ranged from absolute destruction to those chromatolytic changes which we have now learnt to associate with profound disturbance of vital activity.

It is of course possible that this condition was due to the same specific toxic influence that produces primary zoster, and that the condition of the 4th dorsal ganglion, surrounded as it was by new growth, laid it particularly open to attack by the specific disease process. But it seems far more probable that in this case the zoster was directly produced by the secondary inflammation produced in the ganglion by the new growth. It is also certain that so considerable a mass of malignant growth in the foramen must have interfered materially with the blood supply.

In the next case of our series (Case 14) we believe the zoster that made its appearance shortly before death to have been due to direct interference with the ganglion in consequence of injury to the spine.

A man of 36 was struck on the back by a descending lift, and immediately lost motion and sensation below the umbilicus. The analgesia was sharply limited by the upper borders of the 10th dorsal area, but above this area lay a band of intense hyperalgesia, corresponding to the 7th, 8th and 9th dorsal areas on both sides. Six days before his death a small patch of herpetic eruption appeared over the tip of the ninth and tenth costal cartilages.

On *post-mortem* examination the transverse processes of the 11th dorsal vertebra were found to have been fractured, and the 11th and 12th dorsal vertebræ had gone bodily backwards. The 10th, 11th and 12th dorsal ganglia on both sides were surrounded by a mass of inflammatory tissue, and the posterior roots were destroyed partly by actual trauma, partly by inflammation. These changes exactly corresponded with the analgesia discovered during life.

But in addition to these direct traumatic changes, the cells of the 8th, 9th, 10th, 11th and 12th dorsal ganglia on both sides showed profound chromatolytic changes. Thus the disturbance of the ganglion cells was not limited to those ganglia which were implicated directly in the injury (10th, 11th, 12th dorsal), but also extended to the 8th and 9th dorsal, which were not surrounded by inflammatory tissue. Moreover, the 7th, 8th and 9th dorsal posterior roots on both sides showed a curious alteration, in that their medullary sheaths were swollen, their vessels were engorged, and leucocytes were freely extravasated with the connective tissue between the nerve-fibres. We believe that these changes in the ganglia are probably due to interference with their vascular supply, and account for the hyperæsthesia that was present over the 7th, 8th and 9th dorsal segments.

Lastly, the 9th dorsal ganglion stood alone in showing a small focus of inflammatory small round cells situated close to the point where the central vessel of the ganglion gives off its lateral branches. This focus is an extremely small one and can only be taken to explain the small patch of zoster that appeared over the 9th space shortly before death in the light of the other cases we have reported.

This case seems to us to explain the appearance of herpes zoster in cases of caries of the spine. One of us has observed three cases in which an outbreak of zoster corresponded with renewed activity of the tubercular process in the spine. In two of these cases the outbreak of zoster followed the leaving off of a poroplastic support that had been worn for years. Shortly after the support was laid aside pains

in the chest and epigastrium appeared, followed, by an attack of zoster that corresponded in the one case to the 5th dorsal in the other to the 7th dorsal area.

Thus, in conclusion, it would appear that zoster in all respects resembling that arising spontaneously may be produced by implication of a posterior root ganglion in inflammatory processes secondary to malignant disease, tubercle or injury.

Chapter 7.—Zoster arising in the course of Disease of the Nervous System.

In tabes dorsalis outbreaks of zoster form a classical symptom, but this phenomenon is rarer than the text-books would lead us to suppose. One of us, who has seen large numbers of cases of zoster and of tabes during the last eight years, has only met with the conjunction three times. In one case the zoster lay over the area of the third cervical, and was indistinguishable from a severe attack in an otherwise healthy patient. The other two eruptions differed from the common form in that they were scanty, incomplete and tended to come out over a longer interval, which in one of the cases extended to four weeks.

Some light is thrown on this association by Case 17. This man was admitted to Rainhill Asylum for dementia paralytica, but his knee-jerks were absent, and although he could walk he had ataxy of the arms. Thus he was not only a tabetic general paralytic, but was at the same time ataxic. Now it is not uncommon for cases of dementia paralytica to have no knee-jerks and, after death, on microscopical examination of the spinal cord, to show the characteristic lesion of tabes. But it is in our experience less common for such cases to be markedly ataxic during life.

Thus, although this case was one of dementia paralytica, the signs of tabes were so marked that it throws some light on the condition of the nerve-roots in this disease which favours the development of attacks of zoster.

The eruption fell over the 8th dorsal area, and, as in two of the other cases occurring in tabetics, was not profuse.

The 6th, 7th, 8th, 9th and 10th dorsal roots were examined on both sides, and of these several show the following changes:—The sheath of pia mater reflected on to the posterior nerve roots from the spinal cord presents a general inflammatory thickening, and is densely infiltrated with small round cells. In many instances the inflammatory exudation has penetrated the perineurium of individual nerve bundles and given rise to a change in them.

This change is most advanced in the 8th dorsal root of the left side, and here it is not confined to the posterior root, but had spread to the sheath of the ganglion. Running round about one-sixth part of the circumference of the ganglionic sheath, partly upon it and partly within its lamellæ, is a dense collection of small round cells about as deep as the sheath itself. Within the ganglion itself are a few foci of small round-celled infiltration.

Slight as these changes are in the ganglion compared with those in many of the cases we have described above, it is certain that they coincide with a difference between the condition of the 8th dorsal ganglion of the left side and its fellows, for the entry of the 8th dorsal root into the cord on the left side is marked by a field of acute degeneration, which passes up to be lost at the level of the 8th cervical in the usual manner.

This thickening of the pia arachnoid over the dorsal surface of the cord and around the roots is a common condition in cases of tabes; so much so that Obersteiner looks upon it as the essential lesion. Now it would appear that our case shows little more than an extension of this process to the sheath of the ganglion, and just as the small round-cell infiltration had penetrated between the fibres of the posterior root, so the similar change in the sheath of the ganglion had penetrated the substance of this structure. But, on the other hand, it is possible that the changes in the root and in the vessels which are present in tabes had rendered the ganglion more vulnerable to an attack of primary zoster. We are, however, more inclined to the view that the zoster in this case was directly secondary to the disease process of tabes than to the latter hypothesis.

The next case in which zoster appeared in the course of gross organic disease of the spinal cord and roots (Case 16) presents greater difficulties. An eruption, differing in no way from that of spontaneous zoster, appeared, over the 3rd cervical area in a patient suffering from multiple sclerosis secondary to endarteritis obliterans of the small vessels of the nervous system. At the level of the 7th and 8th dorsal roots this vascular change had gone on to complete obliteration of the vessels supplying the anterior half of the spinal cord. This had caused that portion of the cord to be converted into a necrosed mass enclosed in a thickened membrane. Elsewhere in the cord the change was not so advanced, and patches of irregular sclerosis were seen surrounded on their free borders by acutely degenerated fibres (Marchi).

The posterior roots in this case present a singularly interesting condition. When treated by Marchi's method they do not stain well, but become pale and ash gray in colour. Their outlines are indistinct and many of the fibres are slightly swollen. Although none of them show any clearly-marked acute degeneration, leucocytes containing fat and many irregular fat globules are seen lying between the fibres.

The 3rd cervical ganglion on the left side shows many foci of small round inflammatory cells, with destruction of ganglion cells closely resembling the changes seen in ordinary cases of spontaneous zoster, except that we are able to find no hæmorrhages.

We are inclined to think that the zoster in this case was not the direct outcome of the disease of the nervous system from which this patient suffered, but that the endarteritis obliterans and the changes it produced in the whole nervous system predisposed the ganglion to attack by the same unknown agent that produces zoster in otherwise healthy persons.

Amongst the first thirteen cases of our series which we have classed as spontaneous zoster occur three cases in which the outbreak appeared in patients suffering from dementia paralytica (Cases 6, 9 and 10). It might be

thought that such cases should have been associated more rightly with those in the present Chapter, but in none of these cases were any lesions of the spinal cord present other than degeneration in the lateral columns, and the roots were unaffected with the exception of that root passing out of the affected ganglion. Moreover, the nature of the ganglionic lesion differed in no way from that found in the other cases of the spontaneous series.

General paralysis or dementia paralytica undoubtedly disposes to zoster. But this is probably due, not to any direct implication of the ganglia of the posterior roots in the disease process of general paralysis, but to general susceptibility induced by the circulation in the blood of these patients of toxins produced by the breaking down of the higher centres [Mott and Halliburton (35)], by the vascular changes so commonly present in, and the general debility produced by, this disease. Such patients are in the same way unduly susceptible to attacks of acute lobar pneumonia and of dysentery.

Chapter 8.—*Changes in the Skin and Glands.*

§ 1. *Changes in the skin.*—Sections through an unruptured vesicle of herpes zoster show a cavity, the floor of which is formed of naked papillæ. These papillæ are in a condition of profound inflammation and are infiltrated with masses of small round cells which stain deeply. This infiltration with small round cells extends down to the terminations of the sweat glands and hair follicles and here and there small collections of small round cells are seen in the deeper layers of the skin even apart from the hair follicles and sweat glands.

The vesicle is split into incomplete cavities by septa extending from the roof to the floor. These septa are evidently the remains of incompletely-raised epithelial layers that retain their attachment to the roof and to the floor of the vesicle. The cavity of the vesicle is filled with fluid that coagulates under the influence of the hardening agent into a somewhat granular hyaline mass. Within

this mass lie small round deeply-staining cells and broken-down epithelial cells of all sizes and shapes which have lost their prickles.

We have traced nerve twigs up to the portion of skin excised for examinations and found that they showed marked signs of degeneration by Marchi's method, but we have not succeeded in demonstrating degenerated fibres in the actual portion of skin examined.

In 1889, Pfeiffer (21), taking up a position opposed to the nervous origin of herpes zoster, laid stress on certain cells he found in the vesicles. They had a diameter of 30 μ and also occurred in the vesicles of varicella and vaccinia. He nowhere definitely stated they were parasites, but his mind evidently leant in that direction, for he gives a considerable description of diseases caused by protozoa. Hartzell (20) rightly recognised that they were epithelial cells that had undergone degenerative changes. We have seen them in one of the cases we examined, but not in Case 2.

Dr. Hunter, assistant bacteriologist to the London Hospital, has kindly examined the unbroken vesicles in five cases. In most of these cases we took serum from two or more vesicles. In every case the contents of the vesicles were sterile.

Moreover, microscopic examination of the fluid and careful staining of the sections of skin failed to reveal any sign of micro-organisms. Dr. Bulloch kindly stained some specimens of skin in Case 2 and confirmed this result to which we had arrived in other cases.

§ 2. *Changes in the glands.*— The lymphatic glands enlarge and frequently become tender very early in the disease. It is interesting to note that apparently all the areas of the thorax above the 7th dorsal drain into the axilla, whilst all below this area drain into the groin. The 7th dorsal itself and sometimes the 8th dorsal may cause enlargement of either the axillary or inguinal lymphatic glands, or even of both sets.

In Case 2 the enlarged axillary glands were incised two hours after death under rigid aseptic precautions by Dr.

Bulloch, the Bacteriologist to the London Hospital. He could obtain no evidence of bacterial invasion, and sections of the glands revealed no micro-organisms.

But these sections show that the glands were in a profound condition of inflammation. Masses of small round cells can be seen not only in the substance of the gland but also in the trabeculæ.

Thus we are brought face to face with the curious fact that a collection of intensely inflamed vesicles containing a sterile fluid can be associated with enlargement of the lymphatic glands. Moreover, these glands have all the appearance of being inflamed, and yet show no sign of bacterial invasion.

Chapter 9.

§ 1. *Herpes zoster, an acute specific disease of the nervous system.*—A typical attack of zoster arises without any obvious peripheral or central cause, and must be considered an acute specific disease of the nervous system, for it starts with a prodromal period of varying length, during which the temperature is raised. During this period the patient feels ill and has more or less pain; but it is then impossible to make a diagnosis. If the patient is a child, he may be supposed to be sickening for one of the ordinary acute specific diseases. Suddenly, however, after a variable period, the rash comes out and the disease declares itself. The febrile period lasts from three to five days and this may be considered the duration of the acute disease. The rash may appear a few hours after the onset of the disease or may tarry till the fall of temperature. Thus, if the rash be taken to represent the physical signs, an attack of zoster may be compared in these characteristics with an attack of acute lobar pneumonia. For as is well known the signs in the lungs in this disease may be present very shortly after the initial rigor, or may not make their appearance until the crisis is reached. The rash in herpes zoster most commonly makes its appearance on the third or fourth day of the disease, just as the physical signs of acute lobar pneumonia

usually become evident on the third or fourth day after the initial rigor.

If zoster be an acute specific disease, second attacks should be uncommon, and we find as a fact that second attacks are less common than second attacks of measles. We have met with only four such instances in over four hundred cases. Again, the disease should tend to occur more at certain periods than at others or even appear in actual epidemics. This is now recognised to be the case. The records kept by one of us at the London Hospital tend to bear out this statement; for, although sporadic cases occur throughout the year, at certain seasons there is a large increase in the number of cases. Thus, in 1896, 1897 and 1898, there was an epidemic in the middle of March. In 1897 and 1898 there was an outbreak from the middle to the end of May. In 1897 a large number of cases appeared during the long drought that lasted from the end of July until the beginning of November; and during this period of four months fifty-eight cases were seen, or one half the cases of that year. In 1898 several cases appeared together in June, and there was a marked outbreak from the middle of July to the end of August, during which period twenty-two cases were seen in less than six weeks. In the same year another outbreak occurred in the middle of October. Thus there can be little doubt that the occurrence of epidemics of herpes zoster is associated with some atmospheric influence or conjunction of which we are as yet ignorant.

But if herpes zoster is an acute specific disease of the nervous system we find an exactly analogous disease in acute anterior poliomyelitis. This disease begins with malaise and fever. The temperature may remain raised for from three days to a week, and at a variable time during this febrile period, or it may not be until the fever has subsided, paralysis is noticed.

On comparing the pathological condition discovered on microscopical examination in the two diseases their likeness becomes still closer. The following summary of the conditions found in those cases that have died at varying periods in the first few months, given by Allan Starr (45), exactly

corresponds to what can be seen in two cases of this disease we have had the opportunity of examining.[1]

"On microscopical examination there is found a marked hyperæmia of the tissue; all the blood-vessels are engorged and surrounded by exudation alike of serum, of leucocytes, and of small cells. The serum fills the lymph spaces about the vessels and about the nerve-cells. The leucocytes infiltrate the tissues about the cells and cluster around them. There is a great increase of small cells and nuclei in the neuroglia. . . This infiltration of the tissue with leucocytes may be so intense as to obscure all other elements. Ruptured capillaries and small hæmorrhages are seen here and there. It is thus evident that the supporting substance (neuroglia) of the grey matter and the blood-vessels are involved in the inflammatory process.

"The changes in the ganglion cells of the cord are equally characteristic. These cells show great varieties of degenerative changes depending partly upon the severity of the case and partly upon the length of time the process has been going on in any one cell. The earliest change in the cell is the cloudy appearance of its protoplasm, and increased granular appearance obscuring the nucleus and leading to its deeper staining by reagents. In the next stage the cell absorbs stains no longer; the nucleus is faint and the cell has lost its sharp outline and some of its prolongations. Later still the cell appears changed into a swollen, shapeless or spherical ball of matter, and its protoplasm is altered into a homogeneous unstained mass with vacuoles, or has become distinctly granular, in which case it stains deeply. . . The last stage is one of shrinkage, the cell body being changed into a small, deeply-stained mass hardly larger than its original nucleus. . . . . If the case be examined some weeks or months after the onset the vascular changes are no longer evident; the serous exudation has been absorbed, there are no longer leucocytes and cells within the interstitial tissues. . . In some

[1] We owe the opportunity of studying one of these cases to the kindness of Dr. Mott, who has incorporated it in his Croonian Lectures (34). Sections of the other case were kindly given us by Dr. Bulloch.

parts the anterior horn may be changed even into true sclerotic tissue."

If for anterior horn we read posterior root ganglion, and for motor cell posterior ganglion cell, this statement would be an exact description of the changes we have described in Chapter I.

Moreover, the posterior root ganglion is the exact equivalent of the anterior horn. For whereas on the motor side the cells of the neurons of the lowest level lie in the anterior horn, on the afferent side, they happen to lie collected together outside the spinal cord in the posterior root ganglion. Thus zoster might justly be spoken of as acute posterior poliomyelitis.

§ 2. *The nature of the changes that produce herpes zoster.*—The changes which we have described above in the posterior root ganglion, closely resembling as they do those found in the grey matter of the anterior horn in acute anterior poliomyelitis, are typical of a pathological process in the nervous system that has of late years been too much neglected. It is usually dismissed by the statement that it is "of vascular origin." Now if by "vascular" is meant that the disease is directly secondary to occlusion or interference with a vessel, we deny its correctness; if, on the other hand, it is simply meant that the vessels play an important part in the general inflammatory process, it is a platitude.

Many observers have occluded the vessels of the spinal cord for varying periods, and examined the changes so produced in the cells. Such occlusion of the arteries produces marked chromatolytic changes in the cells of the spinal cord, but is not followed by inflammatory changes or hæmorrhages. Leonard Hill ligatured the cerebral arteries in monkeys, and the brains of these animals were examined by Mott (34) at varying periods after the operation. Here, again, extreme chromatolysis of the cortical cells was found, but no inflammatory changes and no hæmorrhages.

Now the universal characteristic of the changes we have described in the affected ganglion is the presence of inflammation in every degree, from scattered collections of

small round cells to profound hæmorrhages in the centre of inflammatory foci. On the other hand, our cases of spontaneous zoster did not show marked chromatolytic changes of the type seen when either the vessels of the spinal cord or of the brain were experimentally occluded. A certain number of ganglion cells seem to be killed outright, and others to be so injured that they quickly die. The remainder, however they may have been changed at the onset of the disease, rapidly recover. Very few, if any, of the ganglion cells appear to be undergoing that steady process of disintegration which we have learnt to associate with the appearances known as chromatolysis.

It is therefore peculiarly interesting to notice that in the two cases of secondary zoster, where we have every reason to suppose that the blood supply of the ganglion was profoundly affected, chromatolytic changes were well marked. In one of these (Case 14), the ganglion was completely surrounded by malignant growth, and in the other (Case 15), the spine had been fractured.

Moreover, secondary degeneration makes its appearance within eleven days of the appearance of the eruption over the whole central projection of the fibres, large and small, in connection with the cells of the posterior root ganglion. This looks far more as if the process were one of acute destruction of ganglion cells than of damage by a poison leading to degeneration and death of the nerve-cell.

Thus it would appear that the changes in the posterior root ganglion consist of an acute interstitial inflammation accompanied by necrosis of the ganglion cells.

Of the nature of the agent which is responsible for this process we are completely ignorant. Microscopically, we have not been able to find any signs of bacterial infection, but have not attempted to make cultivations for fear of spoiling our material for other purposes.

But this agent, whatever it may be, seems to have a specific attraction for the posterior root ganglion exactly as the equally unknown cause of acute anterior poliomyelitis attacks the substance of the anterior horns. Moreover, it is particularly liable to attack the dorsal part of the ganglion, *i.e.*, the portion opposite to the anterior root.

Each posterior root ganglion is supplied by a branch of the arteries in front of the spine (intercostal, &c.). This twig passes in with the peripheral nerve, and courses through the ganglion to meet the branch of either the anterior or posterior spinal arteries. In the ganglion this artery gives off branches towards the periphery, and it is around the terminations of these small branches that hæmorrhages are most often found. Owing to the anastomosis between the arteries of the spinal cord and the branches on the anterior surface of the spine, the ganglion can be injected with colouring material from both directions. If the hæmorrhage is severe it may transgress the territory of the ganglion and occupy the centre of the peripheral nerve (Cases 2 and 4).

It is probable that two ganglia are occasionally affected together. From clinical observation this seems particularly liable to occur with the 2nd, 3rd, and 4th cervical. Unfortunately, no such case is included in our series of *post-mortem* examinations. One case has come under our notice where a true zoster was present at the level of the 8th dorsal on one side and of the 10th dorsal on the other at the same time. Such cases are, however, excessively rare; a similar one has been reported by Kaposi.

Thus the unknown agent responsible for the inflammation in the ganglion not only shows a specific attraction for the posterior root ganglia but commonly attacks one ganglion only. This selection of one group of cells is also partly characteristic of the poison that causes acute anterior poliomyelitis, but as the gray matter of the anterior horns forms a continuous column the inflammatory process has more opportunity of spreading upwards and downwards than in the case of the segmented groups of posterior nerve-cells collected as they are into separate and distinct ganglia.

But we have also to deal with the curious fact that some ganglia seem to be more prone to attack than others, as is shown by the following table compiled from records of 392 cases. No cases are included in which an area was seen in combination with one above or below it.

2nd Cervical	.. 1	3rd Dorsal	.. 34	12th Dorsal	.. 18
3rd ,,	.. 15	4th ,,	.. 38	1st Lumbar	.. 27
4th ,,	.. 21	5th ,,	.. 38	2nd ,,	.. 22
5th ,,	.. 2	6th ,,	.. 20	3rd ,,	.. 5
6th ,,	.. 3	7th ,,	.. 19	4th ,,	.. 1
7th ,,	.. 5	8th ,,	.. 36	5th ,,	.. 2
8th ,,	.. 0	9th ,,	.. 19	1st Sacral	.. 0
1st Dorsal	.. 5	10th ,,	.. 26	2nd ,,	.. 1
2nd ,,	.. 9	11th ,,	.. 22	3rd ,,	.. 5

It will be seen from this table that the ganglia most commonly affected are those which receive afferent impulses from the viscera through the white ramus of the sympathetic (*cf.* Head 30).

Now if any posterior root ganglion is carefully examined it will be found to contain two main groups of cells, large coarsely granular nerve-cells and smaller more pear-shaped cells that stain with methylene blue in a more uniform manner.[1] But the proportion of these two types of cell in any one ganglion varies according to its position. Thus the 6th, 7th, and 8th cervical contain a much larger proportion of large cells than of small ones, whilst from the 3rd dorsal to the 1st lumbar the small cells preponderate. In the 2nd, 3rd, and 4th cervical there is a great preponderance of small cells over large.

Thus the ganglia which receive fibres from the limbs, especially those which receive theirs from the hand (cervical 8) and foot (sacral 1) show a preponderance of cells of the large coarsely granular type. Now, these areas are exactly those which give rise to the long fibres of the posterior columns. For as many observers have pointed out from experiments on animals, and as our observations confirm for man (*vide* p. 374) the postero-internal column in the cervical region is mainly formed by fibres from the leg area, the postero-external by fibres from the arm.

Thus, it would appear that the toxic agent that produces herpes zoster not only has an affinity for the posterior root ganglia, but more particularly for those which contain a preponderance of the smaller type of ganglion cells that give rise to the shorter fibres of the posterior columns.

[1] There is also probably a difference in the processes of these two types of cell, but this will form the subject of a further communication.

But when once a ganglion is attacked all the cells within the area of inflammation suffer, whether they be of the large or small-celled type.

Now these small cells amongst other functions probably subserve that of pain, for Münzer (36) has shown that the long tracts of the posterior columns do not conduct pain impressions to the cerebrum. Hence the intense pain which accompanies an attack of zoster.

But if the case be seen before the rash appears it is sometimes possible to map out the area subsequently occupied by the eruption by means of the hyperalgesia that is present. This hyperalgesia, which closely resembles that so frequently seen as the concomitant of visceral referred pain, is followed by erythema. Then, on the erythematous surface, vesicles appear.

Thus we are inclined to think that the trophic disturbance of the skin is an extreme form of activity of the same cells, disturbance of which by afferent impulses along the white ramus produces the hyperalgesia that accompanies visceral referred pain.

We do not imagine that the eruption of herpes zoster is produced by disturbance of special trophic nerves, but by intense irritation of cells in the ganglion which normally subserve the function of pain, and more particularly that form of pain produced by afferent visceral impulses.

Part II.—The Bearing of the Distribution of the Eruption in Herpes Zoster on Sensory Localisation.

Introduction.

Before this research began one of us had collected a large number of cases of herpes zoster and had constructed a diagram to show the relation that the areas occupied by the eruption bore to one another. A series of segments was thus mapped out upon the surface of the body, and to each segment was given a hypothetical number which was sup-

posed to represent its numerical localisation in the central nervous system. This numerical localisation met with universal disbelief, alike from anatomists and clinicians, and it was therefore felt that if a *post-mortem* examination could be obtained on a case of herpes zoster in which the distribution of the eruption had been carefully drawn or photographed, the question might be settled one way or the other.

But herpes zoster is not a fatal disease, and we felt that the only method by which we could obtain the material we desired was by the study of patients in asylums or infirmaries, a considerable proportion of whom remain in the institution until their death. By this means we have obtained fourteen out of the twenty-one cases we have examined; of the remaining seven cases, we owe three to the kindness of the physicians of Guy's Hospital and four were collected by one of us at the London Hospital. At the same time one of us has collected drawings or photographs of 450 cases that have come under his personal observation.

This material enables us now to deal with the question of numerical localisation in a complete manner. But we wish it to be clearly understood that the segmental areas to which we refer in this paper are those marked out on the skin of the body by the eruption of herpes zoster, and when we speak of an area as, *e.g.*, "the 4th dorsal," we mean that that area corresponds with disturbance of the 4th dorsal ganglion. The question of the identity in position and constitution of these areas with the areas of hyperalgesia that accompany the referred pain of visceral disease, and the relation of these areas to the territory supplied by each posterior spinal root, will be dealt with subsequently by one of us in a separate paper.

On plate 17 we have attempted to combine the typical distribution of each area on a single diagram. Such an attempt is in itself fallacious, for no such combined figure can be absolutely accurate; for on the trunk each area is a band coiled round one half of a rough cylinder, and must therefore vary in each case according to the shape of the trunk. Thus one of these areas extended around the abdomen of a baby will have a completely different appear-

ance from the same area around the waist of a woman who wears stays. An eruption produced by a lesion of the 6th dorsal ganglion will differ considerably when extended on the narrow sloping chest of the phthisical or on the barrel-shaped, high shouldered thorax of the emphysematous. Bony points are thus almost useless: skin points only are trustworthy, and of these we unfortunately possess only the nipple and the umbilicus.

We are also confronted with another difficulty which must always make such a combined diagram incomplete; for the supply of the afferent ganglionic fibres is subject to variation, and any one portion of skin may be supplied in the one patient by the fibres that enter one ganglion, in another by those that enter the ganglion above or below. We hope, however, to be able to show the extent to which this variation may occur and the laws by which it is governed.

Lastly, we shall deal with the question of interdigitation and overlap in as far as it affects the areas mapped out on the body by the eruption of herpes zoster.

§ 1. *The numerical localisation of the areas marked out by the eruption of herpes zoster.*—When the original diagram of the areas on the surface of the body was published by one of us (27), Thane (46) summed up the criticism of the anatomists in the following passage:—"It may be pointed out that the areas as designated do not always agree with the distribution of the corresponding nerves as determined anatomically. Thus the area marked D 3 on the inner side of the arm corresponds rather to the brachial distribution of the 2nd dorsal nerve through its intercosto-humeral branch and the communication with the nerve of Wrisberg, while the third dorsal nerve does not usually contribute largely to the supply of the arm. Similarly the areas marked D 11, D 12, and L 1, would seem on anatomical grounds to correspond more nearly to the 12th dorsal and 1st and 2nd lumbar nerves."

Thorburn (48), is equally definite: ". . . If we trace Head's areas downwards we find other evidences of a tendency to describe them as being a segment or part of a

segment too high. . . . If, however, we turn to the lower part of the diagram there appears to be a tendency in an opposite direction, that is, the areas are depicted too low. Thus it will be seen that his 1st lumbar region corresponds more closely to that which Starr and others besides myself assign to the 2nd lumbar, and anatomical dissection shows that the 1st lumbar nerve is mainly distributed above the line of Poupart's ligament where Head has the 12th dorsal . . . and finally, the umbilicus probably lies, not as Head places it at the junction of the 9th and 10th dorsal fields, but certainly no higher than the lowest part of the 10th."[1]

The combined diagram we give differs somewhat from that on which these criticisms were written, but the differences lie in the form of the areas and not in their general position. A greatly increased number of cases has enabled us to bring the form of the various bands more nearly to that which we consider normal. But we still maintain that the 3rd dorsal usually supplies part of the inner side of the arm, that the 5th dorsal sends fibres to the lower part of the breast, that the umbilicus lies between the 9th and 10th dorsal areas, and that the 12th dorsal supplies the skin partly above and partly below Poupart's ligament.

The following table of the segments from the 3rd cervical to the 1st lumbar shows those we have examined:—

Cervical 3.—Examined twice. Case 6, fig. 6, and Case 17, fig. 17.
Cervical 4.—Case 10, fig. 10.
Cervical 5.
Cervical 6.
Cervical 7.
Cervical 8.
Dorsal 1.
Dorsal 2.—Case 7, fig. 7.
Dorsal 3.
Dorsal 4.—Examined twice. Case 11, fig. 11, and Case 14, fig. 14.
Dorsal 5.
Dorsal 6.—Examined twice. Case 3, fig. 3, and Case 13, fig. 13.
Dorsal 7.—Examined twice. Case 2, fig. 2, and Case 9, fig. 9.
Dorsal 8.—Case 16, fig. 16.

[1] The interesting monograph by Wichmann, "Die Rückenmarksnerven und ihre Segmentbezüge," did not reach us until our paper was already in print. As far as the trunk is concerned, his figure of the sensory segments more closely resembles that of Head (30) than any other scheme. However, he places the umbilicus in the centre of the 10th dorsal field.

Dorsal 9.
Dorsal 10.
Dorsal 11.—Case 5, fig. 5.
Dorsal 12.—Examined three times. Case 4, fig. 4; Case 8, fig. 8; and Case 12, fig. 12.
Lumbar 1.—Case 1, fig. 1.

Thus out of nineteen consecutive areas we have examined ten, and of these ten we have examined five more than once.

Amongst these cases we are fortunate in having several that include the disputed points. Thus Case 11 and Case 14 show how the 4th dorsal lies above the nipple, supplying, in a woman with large breasts, the upper half of the mammæ and sending a branch to innervate the upper half of the areola.

The 11th dorsal, and not the 12th, supplies the groin just above Poupart's ligament (Case 5), and thus it is certain that the umbilicus lies between the 9th and 10th dorsal areas.

Again, we are fortunate in having examined in three cases the 12th dorsal area, upon which universal doubt has been thrown (Case 4, Case 8, Case 12). The extent of the eruption varied in each of these cases, and the conditions of this variation will be considered in the next section. But in all these cases the eruption lay below the crest of the ilium, and extended on to the outer side of the thigh below Poupart's ligament. Moreover, as additional proof, we have examined one case of the first lumbar area, which, though the rash had not developed in front, it was sufficiently well marked, posteriorly and laterally, to confirm the numerical localisation.

Thus if ten out of nineteen consecutive areas have been found by *post-mortem* examination to be correctly numbered, it is unlikely that there is any serious error in the numbering of the remainder.

§ 2. *Variation in form without variation in nerve supply.*—The primitive form of these segmental areas is a band passing around the body from mid-dorsum to mid-venter. The 6th dorsal still retains this primitive character in an almost unaltered form. It starts from the mid-dorsum opposite the 7th and 8th dorsal spines, and passes

forward beneath the angle of the scapula. It dips a little in the axilla and swings forward beneath the lower border of the mamma to end in front over the fifth interspace. In its course it passes over the eighth, seventh and sixth intercostal spaces.

If the eruption over this band-like area is examined carefully it is seen to be made up of three main outbursts. The most posterior of these extends from the middle line of the back to about the line of the angle of the scapula, and obviously represents the supply of the posterior primary division. A second outburst takes place in the axilla, and from this point the eruption streams backwards and forwards, representing the lateral cutaneous branch of the anterior primary division. Lastly, over the fifth space in front of the nipple line is a third small outburst corresponding to the terminal twigs of the anterior primary division.

Thus in its complete and primitive form each of these segmental areas consists of a dorsal, a lateral and an anterior division. It is by the changes in the relative proportions of these three constituents that the areas in different regions arrive at their peculiar shape. Passing upwards from the 6th dorsal, we find a tendency for the lateral outburst to be pulled upwards towards the apex of the axilla. This tendency to lateral extension is still more marked in the 3rd and 2nd dorasl, where the lateral flap extends on to the ulnar surface of the arm and reaches its culmination in the detached lateral flap of the 1st dorsal, with its minute anterior and posterior flaps.

Below the 6th dorsal the posterior flap tends to extend downwards on the back, so that its ventral apex may lie below the dorsal apex of the lateral portion of this area. At the same time the lateral and anterior branches of the anterior primary division tend to form a rough triangle on the abdomen. The lower border of every area below the 6th is pulled somewhat downwards towards Poupart's ligament, but rises again towards the middle line of the abdomen. Thus the 9th dorsal area does not touch the middle line of the abdomen at any point below the umbilicus, but its lower border frequently lies considerably below the horizontal level of the umbilicus.

With the 1st lumbar on the front of the thigh and on the buttock, this tendency for the lower border to become dragged downwards becomes well-marked, reaching its culmination in the extraordinary shape of the 3rd lumbar. Below the knee the 4th and 5th lumbar and 1st sacral have entirely lost their anterior and posterior attachments, and consist of the remains of the lateral flap only.

Now it is at once obvious that such a condition offers many opportunities for variation apart from any change in the actual nerve supply. For such an area as the 10th dorsal spread round the abdomen of an infant is a broad almost horizontal band; but on the waist of a woman, especially if she belong to the long-chested type, this area comes to resemble two triangles, in each of which the widest angle is directed towards the leg. The trunk of an infant so much more nearly resembles a cylinder that all the areas, from the 3rd dorsal to the 1st lumbar, tend to become horizontal bands, whereas in the adult they more nearly resemble a couple of obtuse-angled triangles.

Then, again, the trunk of an infant forms a proportionately much larger part of the whole body than in an adult. Thus the areas on the front of the thigh of a young child appear to be smaller and more band-like than those of an adult.

The distribution of these segmental areas on the breast requires special consideration. We will begin with the chest of a young male where the nipple is situated over the lower border of the 4th rib. In such a case the anterior limb of the 3rd dorsal will send a minute downward tag that almost reaches the inner side of the base of the nipple. The anterior axillary branch of the 4th dorsal sends a tag that runs upwards and forwards to end on the outer side of the nipple, whilst the small anterior flap supplies the upper and anterior portion of this structure (fig. 14, Case 14). Thus at least one-quarter of the nipple lies below the lower border of the 4th dorsal area. The 5th dorsal sends an upward projection from its upper border to envelop this portion of the nipple.

This description also applies to the undeveloped breast

of a young girl; but as soon as the breast of a woman increases in size, the appearance of these three areas alters profoundly, although on analysis their relations to one another are seen to remain unaltered. The downward tag from the 3rd dorsal becomes of much greater importance, covering a considerable portion of the upper surface of the breast. The forward branch of the lateral flap and the termination of the anterior primary division now become a very prominent feature of the 4th dorsal area, and supply the whole outer and the whole inner quadrant of the mammæ (fig. 11, Case 11.). The 5th dorsal supplies the whole under surface of the mammæ, except that when it is considerably enlarged as in a suckling woman, the upper border of the 6th dorsal laps onto that part which lies over the fifth space and sixth rib.

Into this category we are inclined to place the different appearances presented by the eruption in the three cases where the 12th dorsal ganglion was found to be affected. We regard fig. 8 (Case 8) as the most usual appearance of this area, for it corresponds with the majority of the cases where this area was represented amongst the 450 of our collection. In fig. 12 (Case 12) the downward projection on to the thigh is much less marked, whilst in fig. 4 (Case 4) two long streamers occupy much more of the outer side of the front of the thigh. Yet in all these cases the superior border occupied the same position and the point reached by all three cases in the mid-ventral line was identical.

Thus in conclusion we wish to point out that these areas may differ markedly in different individuals owing to variations in the surface of which the skin is stretched without any necessary alterations in nerve-supply.

§ 3. *Variation in nerve-supply.*—In order to investigate to what extent these areas were liable to true variation, it became necessary to select one of them and to examine as many cases as possible where the eruption lay over that area.

The area selected for this purpose must be easily localised, have well marked anterior, posterior and lateral flaps, and occur with sufficient frequency in a complete form. These conditions are best fulfilled by the 3rd dorsal.

The form assumed by this area, which we consider to be normal, is characterised as follows: The upper border of the posterior flap starts at the 3rd dorsal spine, slopes slightly downwards and then rises to cover the spine of the scapula. From this point it slopes downwards towards the arm to be continued into the posterior border of the lateral flap. The lower border starts behind, about an inch below the upper border, but then slopes rapidly downwards over the scapula, rising again with the external border of that bone to enclose a triangular patch somewhat resembling in shape the lower part of the scapula itself.

The lateral flap covers the upper half or two-thirds of the post-axial border of the arm. Thus, when the arm is raised to a vertical position, with the ulnar border of the forearm and the little finger facing the observer, the lateral flap should appear in its entirety extending one-half or two-thirds of the distance towards the elbow.

The upper border of the anterior flap touches the lower border of the second rib, and the lower border dips on to the region of the mamma to reach a point just above the areola of the nipple. From this point it rises to end over the third rib cartilage.

Out of twenty complete cases in which the eruption lay over the 3rd dorsal, twelve followed exactly this course.

Now if this area were prefixed, *i.e.*, moved up somewhat nearer the head end of the nervous system, we should expect it to show a closer resemblance to the 2nd dorsal than when it assumes what we have called the normal form. That is to say, the upper border of the posterior flap would lie along or above the spine of the scapula and the lower border leave a considerable part of the subspinous portion of the scapula uncovered. The lateral flap would extend further down the axillary border of the arm and nearly reach the elbow. The upper border of the anterior flap would run along the upper border of the 2nd rib, and the lower border would end some considerable distance above the nipple.

This was exactly the area occupied by the eruption in one case out of the twenty cases.

If, on the other hand, this area were post-fixed, *i.e.*, pushed nearer the tail end of the nervous system, it would more closely resemble the 4th dorsal than normal. The upper border of the posterior patch would scarcely touch the spine of the scapula and the lower border would come closer to the angle of this bone, covering a larger portion of the subspinous area. The lateral flap would be shortened so as only to occupy a few inches of the axillary border of the arm. The upper border of the anterior patch would lie over the 3rd rib and the lower border would send a downward tag to envelop the nipple from above.

This condition occurred in seven out of the twenty cases.

Thus out of twenty cases where a well developed eruption occupied the area of the 3rd dorsal, twelve were what we have called normal, one was prefixed, and seven were post-fixed. We do not look upon these figures as more than an indication of how this area may vary; for twenty cases are too few to form the basis of any statistical conclusions.

We believe, however, that the areas on the trunk are less liable to true variation than those on the limbs. Those which affect the terminations of the limbs are the most variable of all, but the infrequency with which they appear renders a more definite statement impossible.

It might be objected that the instances given above are not cases of variation but of false enumeration. This is rendered improbable by comparing the two cases in our series (Case 3 and Case 13) in which the *post-mortem* examination showed the 6th dorsal to have been affected. In Case 3, that of a child, the eruption (fig. 3) ran almost straight round the body, passing just below the angle of the scapula and below the nipple. In Case 13 on the other hand, the upper border of the eruption (fig. 13) touched the lower angle of the scapula and passed forward beneath the nipple, sending an upward tag to just implicate the lowest part of the areola. Yet in both these cases the *post-mortem* examination showed that the 6th dorsal was affected. Now the eruption in Case 3 followed what we should call the normal course; in Case 13 it was pre-fixed. Moreover, this eruption showed exactly the characteristics we laid

down as necessary for a pre-fixed area, when discussing the variations in the 3rd dorsal; for it resembled the area above it, the 5th dorsal, in sending a branch to the nipple, and yet its upper border was distinctly lower than that of a normal 5th dorsal.

So far we have met with no case where an eruption that lay entirely over an area to which we had habitually given one number, turned out on *post-mortem* examination to have been due to an affection of the ganglion above or the ganglion below. That is to say, in each case where from examination of a previous case we had been led to suppose that the 3rd cervical, the 4th dorsal, the 7th dorsal, or the 12th dorsal would be affected, the enumeration again turned out to be correct.

Thus, in conclusion, we believe that when a certain ganglion is affected the eruption most frequently lies over a definite tract of skin, which may be called the normal area from which fibres enter that ganglion. This tract of skin may, however, in some cases be situated further headwards, and occupy about one-half or less of the area usually supplied by the segment in front (pre-fixed). It may also be situated further towards the tail end of the body, and occupy about one-half or less of the area usually supplied by the segment behind it (post-fixed). But its displacement never exceeds half an area in either direction, and in no case did we find that an eruption, which lay over what we supposed to be the complete normal area of a certain segment, was produced by a lesion of either the ganglion above or the ganglion below.

§ 4. *Overlap and Interdigitation.*—After what we have said in the preceding sections concerning the possibility of change in the shape of these segmental areas owing to individual differences in the shape of the patient's body or to actual variation of nerve-supply, it will at once be seen how difficult it is to determine to what extent these areas overlap. Thus in every case it becomes necessary to consider whether the area occupied by the eruption belongs to the normal type. If this be so we can then only determine the extent of the overlap by comparing it with the normal

distribution of the area in front of it and the area behind it in a case where the body of the patient was of approximately the same shape. For it is useless to attempt to compare the 10th dorsal, however normal it may be, when spread out round the body of a baby, with the 9th dorsal around the small waist of a woman in the hope of determining to what extent these two segments overlap.

A third difficulty with which we have to deal is the extraordinary interdigitation of the serrated margins of these areas. They can rarely be defined by straight lines, for the eruption is made up of a series of outbursts, each of which follows the course of a tiny nerve-twig. Now it is quite impossible to say how far the downward tags of one area fit into the notches of the area below, but all we can say is that if the downward tag is a large one and forms an integral and distinctive feature of the area in its normal form, a notch of greater or less depth will be found in the area below corresponding, though not to the full extent, with this downward projection of the area above. (Compare the downward course of the posterior patch in fig. 5 with the notch in the upper border of the posterior patch of fig. 8 and fig. 4).

Let us then first compare the extent of the eruption in Case 2 or Case 9, which occupied the 7th dorsal area, with that of Case 16, that lay over the 8th dorsal. All these cases were men, and the rash in Case 2 was almost identical with that in case 9. It will be seen that the lower border of the area in figs. 2 and 9 scarcely encroaches at all on the upper border of that in fig. 16. Moreover, the apex of the anterior half of the eruption in fig. 16 fits into the notch made by the junction of the anterior with the posterior half of the area in figs. 2 and 9. In fact, the overlap does not consist of one-third of the extent of either of these areas. This slight overlap we believe to be typical of the areas of the trunk.

Turning next to the cervical region, fig. 6 shows a typical third cervical, and fig. 10 a fourth cervical with a rather extended anterior border, but a normal posterior border. In both cases the patients were men. It will be

seen that the anterior or cephalic border of the fourth cervical (fig. 10), lies over the area occupied by the third cervical (fig. 6). But although these two areas habitually overlap, the extent of the overlap is not so great as might at first sight appear, for the third cervical runs in two main streams across the outer part of the supraclavicular fossa, and between these two streams the skin is affected either lightly or not at all. In the same way the anterior or cephalic portion of the fourth cervical (fig. 10), which also covers the outer part of the supraclavicular fossa, is always lightly marked both by erythema and vesicles in obvious contrast to that part which lies over the shoulder.

We believe that the overlap is more marked on the limbs, especially at their termination, but owing to the comparatively small number of cases on the fore-arm and leg (p. 394) it is impossible to be certain of the amount of this overlap.

Thus, in conclusion, the areas marked out by the eruption of herpes zoster overlap one another to a very variable extent. On the trunk this overlap is slight when individual differences and variation in nerve-supply are taken into account. In the neck this overlap consists more of a sharing of a certain territory than of true overlap, but on the limbs, especially at their termination, the overlapping is distinct.

Yet in no case does the zone of overlap equal in extent more than one-half of the area above and below, whilst in many cases it is considerably less.

Part III.

Case 1.—John William K., aged 64. Marylebone Infirmary (Mr. Lunn). Died February 23, 1897.

Summary.

No history obtainable.

Admitted for paraplegia. Paralysis extended as high as lower ribs on both sides. Cystitis and retention of urine.

Herpes appeared over the 1st lumbar area on the left side three days before death and continued to come out up to death.

Myelitis of the spinal cord as high as the upper dorsal region.

The 1st lumbar ganglion on the left side showed a large hæmorrhage in the centre with much surrounding infiltration by small round cells that stained deeply with Nissl's blue. The ganglion cells were destroyed, and those which remained failed to stain with Nissl's blue in the presence of a counter stain.

The remaining ganglia were normal.

The peripheral nerves showed no change.

Beyond marked degeneration of the vessels the brain showed no change.

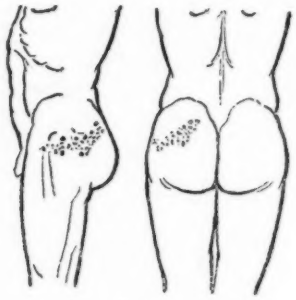

FIG. 1.

To show the distribution of the eruption in Case 1.

He was admitted to the infirmary on February 10, 1897, for paraplegia and complete incontinence of urine and fæces. He was completely paraplegic up to the level of the lower ribs and the abdominal muscles were paralysed. He was semi-comatose, with a temperature of 101·6° F. and sensation could not be tested. He was said to have incontinence of urine, but on admission his bladder was over-full and the incontinence appeared to be due to overflow.

On February 19 an herpetic eruption appeared over the area in fig. 1, and was still coming out when he died on February 23.

Thus the herpetic eruption began to appear three days before death.

POST-MORTEM EXAMINATION.

Made forty hours after death in cold weather. From a few hours after death until the examination the body lay upon its face surrounded by ice. It was found to be in excellent condition at the examination.

No bed sores.

Lungs showed much hypostatic congestion but there was no pneumonia. The substance of the heart was extremely soft and of a brown colour with marked striation. No valve lesion.

Spleen of normal size, but soft. Capsule of the kidneys stripped with fair ease and did not bring away the cortex. Cortex perhaps a little diminished. Liver normal.

The bladder showed marked thickening from old cystitis and the mucous membrane was of a purple-red colour.

Brain.—Arteries extremely degenerated and atheromatous, and in some places they were almost blocked by white clot. The cortex was well developed and showed no marked wasting. Membranes stripped easily and without decortication. Ventricles not distended nor granular. No hæmorrhage. No softening.

The lower portion of the cord was very soft and almost diffluent from myelitis.

Microscopical Examination.

A microscopical examination was made of (*a*) a series of posterior root ganglia, (*b*) a series of peripheral nerves, (*c*) the spinal cord.

(*a*) *Ganglia.*

Dorsal 12, lumbar 1, 2, 3, 4, 5, of both sides were fixed in 96 per cent. alcohol and imbedded in paraffin. Sections were cut, mounted in strict series and stained by Nissl's method, Held's methylene blue and erythrosin, and with methylene blue and eosin.

Dorsal 12.—The vessels of the sheath of this ganglion on both sides were much engorged, but otherwise no gross change was present.

Lumbar 1. *Left.*—When the ganglia were completely hardened it was at once evident that this ganglion differed from its fellows. It was smaller, and at the same time much softer than any other ganglion of the series, and whereas the other ganglia were hard and resistent to the finger the 1st lumbar ganglion of the left side had the semi-fluid feel of an over-ripe gooseberry. It was therefore divided transversely across the centre with a sharp razor, and was then seen to contain a mass of soft pulpy material in the centre. The two halves were embedded and cut together so that the exposed surface corresponded to the incision through this soft central mass.

The following changes in an extreme form extend over forty sections. The centre of the ganglion is occupied by a large space with ragged edges. In sections taken from either end of the ganglion the centre is seen to be composed of effused blood more or less altered and surrounded and infiltrated with fibrin. Towards the periphery of this focus are a large number of small round cells which have stained deeply with methylene blue.

Amongst the débris in the centre no remains of ganglion cells or normal ganglionic structure can be seen, but in the peripheral layers broken down ganglion cells can be seen, staining in some cases a rich golden colour. The contrast between these ganglion cells and the small round cells, with their deep blue staining, is marked. Between the focus of destruction in the centre and the ganglionic sheath are many ganglion cells which have stained pink with erythrosin or remained pale.

Thus the centre of this ganglion is occupied by a large hæmorrhage which had completely destroyed it, whilst around this central focus lie ganglion cells that were either dead or markedly altered in vitality before the death of the patient. Moreover, the whole of the ganglion around the central focus of destruction is filled with small round cells that stain deeply with methylene blue.

At the level where this change is best marked the anterior root is seen as a compact bundle lying in its own subdivision of the ganglionic sheath.

The sheath of the ganglion shows no thickening and no marked alteration of any kind.

Lumbar 1. *Right.*—The cells of this ganglion do not stain well with Nissl's blue, but there is no hæmorrhage and no infiltration with small round cells. The central vessel is well seen and contrasts well with the hæmorrhagic focus in a similar position in the ganglion of the left side.

Lumbar 2.—Neither right nor left ganglion show any marked change.

Lumbar 3 *and* 4.—None of these ganglia show any change.

(*b*) *Peripheral Nerves.*

The peripheral branches of the 12th dorsal, 1st, 2nd, and 3rd lumbar were stained by Marchi's method and examined in teased specimens and by sections, but no change was found.

(*c*) *Spinal Cord.*

As high as the upper dorsal region the whole area between the posterior horns was markedly destroyed. The vessels appeared to be plugged with clot of some standing, and the posterior columns were converted into a mass of débris consisting of broken-down fibres and a large number of small round cells, apparently leucocytes.

In the mid-dorsal region this disintegration extends in an irregular manner into the lateral columns. Thus the cord showed myelitis mainly affecting the posterior columns, but also invading to a less degree other portions of the cord as high as the upper dorsal region.

Above this no change is seen except the universal thickening of the walls of the vessels of the pia arachnoid.

Case 2.—James T., aged 35. Admitted to the London Hospital October 31, 1899. Died November 2, 1899.

SUMMARY.

A case of aortic obstruction and regurgitation. Admitted for cardiac failure with swelling of legs. Death followed two days after admission.

An extremely severe herpetic eruption was present over the area in fig. 2 *corresponding to the* 7*th dorsal segment. It had begun to appear seven days before admission or nine days before death.*

Microscopically, the 7*th dorsal ganglion on the right side was found to be profoundly affected. The whole ganglion was infiltrated with small round cells and more than half the ganglion was riddled with extravasated blood.* (*Plate* 1, *fig.* 1.)

The peripheral nerve trunk for nearly 2 *cm. from the ganglion showed profound inflammatory changes with an effusion of blood into the centre of the swollen nerve, changes identical with those in the ganglion.*

The 5*th*, 6*th*, 8*th, and* 9*th dorsal posterior root ganglia and the* 7*th dorsal ganglion of the left side were normal.*

No secondary degenerative changes were found in the posterior roots or spinal cord.

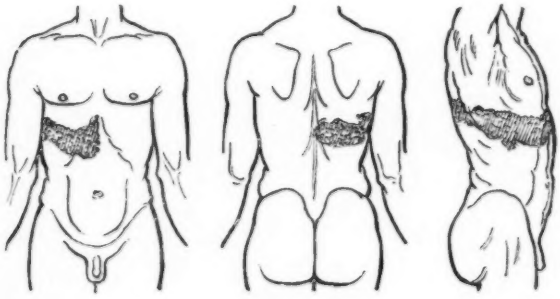

FIG. 2.

To show the distribution of the eruption in Case 2.

History.—His speech has been husky for two years and he has had cough and increasing weakness for one year. On November 1, 1898, he was seized with pain over the heart which lasted for three hours. He then slept for two hours and woke without pain, but with dyspnœa which prevented his lying down

for three or four days. Since that time he has had frequent attacks of a similar kind. For the last eight weeks his legs have been swollen and he has been obliged to sleep in a chair for more than a week.

There is no history of rheumatism in any form, but he admits syphilis.

On admission he was extremely ill and lay propped up in bed with head thrown back on his pillows. His face was a little puffy and his legs and thighs œdematous. There was an extremely marked and severe herpetic eruption on the right side over the area in fig. 2 corresponding to the 7th dorsal. It had first appeared on October 24, and had now reached its full development.

He suffered from no pain, but had dyspnœa with a short cough at times. The sputum was muco-purulent.

Cardiac impulse heaving, diffuse and fairly regular, situated in the 6th intercostal space. An aortic systolic and diastolic murmur was audible, but there appeared to be no mitral systolic murmur.

There was dulness with absence of breath sounds and vocal resonance over the left base.

The urine contained one-fifth albumen.

Progress.—On the evening of November 1 he had a severe cardiac attack during which his pulse became irregular. He rallied somewhat after venesection, but died in the early morning of November 2, nine days after the appearance of the herpetic eruption.

Post-mortem Examination.

Eight hours after death, in cold weather.

The right pleura contained two pints of clear fluid; the left was obliterated by old adhesions. Both lungs were emphysematous and congested. The left base was infiltrated with bronchopneumonic patches to such an extent that portions of the lung sank in water.

The heart weighed 16½ oz. (467 grammes). Both sides were much enlarged. The left ventricle was dilated but not much hypertrophied, and parts of its wall were markedly fibrous. The right ventricle was dilated and its wall was hypertrophied. The aortic valves were much thickened and puckered, especially at the attached and free margins. The mitral valve was slightly thickened and admitted three fingers easily. Pulmonary and tricuspid valves normal. There was extreme atheroma of the aorta.

The spleen weighed 7½ oz. (212 grammes). The kidneys contained one or two small cysts and the capsule was slightly adherent. The cortex when stripped was a little irregular. They were of normal size. The liver weighed 4 lb. 3 oz. (1899 grammes) and was slightly fatty.

The brain was normal in colour and size. Its arteries were tough, but showed no nodular thickening. The membranes were normal and stripped well. Pons, cerebellum, medulla, and cord normal to the naked eye.

Microscopic Examination.

A microscopic examination was made of (*a*) a series of posterior root ganglia, (*b*) a series of nerve roots, (*c*) a series of peripheral nerves, (*d*) the spinal cord, (*e*) the skin within the herpetic area, (*f*) certain lymphatic glands.

(*a*) *Posterior Spinal Ganglia.*

The 5th, 6th, 7th, 8th, and 9th root ganglia were dissected out and hardened for four hours in corrosive sublimate, washed in running water for sixteen hours, and placed in 30 per cent. spirit. From this strength they were gradually carried up to absolute alcohol. They were then embedded in celloidin and cut in series of longitudinal sections.

Dorsal 7. Right.—When the 7th dorsal ganglion of the right side was dissected out it was at once obvious to the naked eye that it was different from its fellows. It was not reddened but looked swollen. Moreover, that portion of the peripheral nerve close to the ganglion was obviously swollen, being for a short distance nearly as thick as the ganglion itself. This portion was hardened and embedded with the ganglion and cut longitudinally.

Microscopically (plate 1, fig. 1), the early sections, which include the sheath only, show extremely marked engorgement of the vessels, and over the swollen portion of the peripheral nerve blood seems in places to have escaped from the vessels. The sections through the ganglionic substance itself show three well-marked changes. Firstly, there is a great increase of small round cells which lie packed in thick clumps between the ganglion cells. These cells stain well with methylene blue. Secondly, the whole of that half of the ganglion on the side opposed to the anterior root bundle is honeycombed with small hæmorrhages. Long streaks of extravasated blood run almost parallel to the contour of the capsule, and multitudes of small hæmorrhages dot the substance of the ganglion. Thirdly, wherever the small round-celled infiltration is marked, and in the neighbourhood of each hæmorrhagic spot, the ganglion cells have undergone a profound change. If a nerve-cell lies in the centre of a hæmorrhage it does not stain at all with methylene blue, and in specimens prepared by the Nissl method appears as a white ghost. Such cells, however, stain readily with eosin or saffranin. If these cells are examined under a high power they are seen to be broken up into fine globular masses, and here and there they are eroded by leucocytes that have invaded their

capsule. There is no vacuolation or extrusion of nuclei. The cells have the appearance of a tissue that has been suddenly killed. On the other hand, in those parts of the ganglion which contain no hæmorrhages but are infiltrated with small round cells, the ganglion cells are seen under a low power to stain fairly well, but under a high power they present a ground-glass appearance with some reduction of Nissl bodies, but no vacuolation or alteration in the nuclei. Thus, considering that the ganglia were hardened in corrosive sublimate, these cells cannot be said to show any marked change; for the appearances obtained in posterior root ganglion cells with this fixative differ from those that follow alcohol hardening, although in themselves they are equally constant and characteristic.

Left.—This ganglion is normal and shows none of the changes present in that of the right side.

Dorsal 5, 6 *and* 8. *Right and left.*—All normal.

(*b*) *Posterior Nerve-roots.*

The 5th, 6th, 7th, 8th, and 9th dorsal roots of both sides were stained by Marchi's method. In no case could any definite signs of acute degeneration be discovered. The 6th and 7th dorsal roots on both sides were stained by Stroebe's method (after treatment by Marchi's method), and no change could be discovered.

(*c*) *Peripheral Nerves.*

Rather more than 1 cm. of the peripheral nerve of the 7th dorsal on the right side remained attached to the ganglion, and was hardened, cut, and stained with that structure (*vide supra*). It showed signs of inflammation and hæmorrhage, exactly resembling the changes seen in the ganglion.

The posterior primary division and the anterior trunk of the 6th, 7th, and 8th nerves on both sides were treated by Marchi's method. No change could be discovered.

(*d*) *Spinal Cord.*

The spinal cord was hardened in Müller's fluid, and every segment above the 9th dorsal was cut in celloidin. No change of any kind was discovered.

(*e*) *The Skin within the Area covered by the Eruption.*

Portions of skin on which the eruption was still well marked at death were hardened in a saturated solution of corrosive sublimate and cut in the usual manner. They were stained for micro-organisms, but without result. Moreover, inoculations were made

from the vesicles on many different media, but in every case they remained sterile. These observations were kindly made for us by Dr. Bulloch, bacteriologist to the London Hospital.

Sections through an unruptured vesicle show a cavity, the floor of which is formed by naked papillæ. These papillæ, in a condition of profound inflammation, are infiltrated with masses of small round cells, which stain deeply. This infiltration with small round cells extends to the termination of the hair follicles and of the sweat glands. Here and there small collections of deeply-staining round cells are seen even in the deeper layers of the skin, apart from either sweat glands or hair follicles.

The vesicle is split up into incomplete cavities by irregular septa extending from the roof to the floor. These septa are evidently the remains of incompletely-severed epithelial layers. The cavity is filled with a fluid that has coagulated into a somewhat granular hyaline mass under the influence of the hardening agent. Within this mass lie small round deeply-staining cells and broken-down epithelial cells of all sizes and shapes, which have lost their prickles. In this case we were unable to see any of the large polynuclear cells not infrequently found in such vesicles.

(*f*) *Axillary Lymphatic Glands.*

It was noticed during life that the glands lying under the posterior border of the pectoralis and in the summit of the axilla were enlarged and tender. They were therefore incised two hours after death with rigid aseptic precautions, and cultivations were made from them by Dr. Bulloch. They were uniformly sterile.

The glands were removed and hardened in corrosive sublimate. Sections showed no micro-organisms.

Yet these same sections showed that the glands were in a condition of profound inflammation. Foci of small round-celled inflammation are scattered throughout, not only the glandular portion, but also throughout the trabeculæ.

Case 3.—John K., aged 5. Admitted to Guy's Hospital, April 9, 1897. Died April 21, 1897 (Dr. Pye-Smith).

SUMMARY.

Admitted for acute bronchitis. Herpes zoster appeared on April 11 *over the area in fig.* 3 (*dorsal* 6). *Death eleven days after from tubercular broncho-pneumonia and miliary tuberculosis. Acutely degenerated fibres were seen to enter the cord by the* 6*th dorsal root on the right side. This degeneration extended up in the posterior column as high as the level of entry of the* 2*nd dorsal root.*

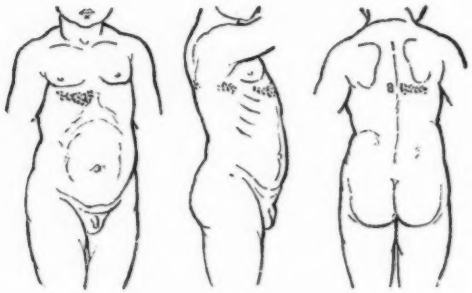

FIG. 3.

To show the distribution of the eruption in Case 3.

On admission the patient was a small fair boy in fairly good condition, and with no evidence of rickets. His temperature was 101°.

Respiration 30. Much dyspnœa and cyanosis. Mucous râles heard all over the chest.

Pulse 156, small and irregular. Heart sounds faintly heard.

Urine acid; contains no albumen or sugar.

April 11. Herpes zoster has appeared occupying an area behind corresponding to the eighth rib, whilst in front the eruption is situated over the fifth and sixth intercostal spaces. In the axilla is a third (lateral) patch situated on the horizontal level of a line joining the anterior or posterior patches (fig. 3).

April 21. Died at 8.30 p.m.

POST-MORTEM EXAMINATION.

The bronchial glands were caseous, and one of considerable size was adherent to the left bronchus. Tubercles were scattered throughout the lungs, and some tubercular foci had begun to caseate. Both bases were collapsed, and showed in addition patches of broncho-pneumonia.

Heart normal.

Spleen was enlarged and contained tubercles of various sizes on its surface and throughout its substance.

Kidney contained a few tubercles.

Liver weighed 794 grammes. Tubercles seen on its surface. A little recent capsulitis.

The spinal cord was removed, but as neither of us was present at the *post mortem*, unfortunately no ganglia were dissected out. The spinal cord was preserved in Müller's fluid and passed into the hands of one of us a few days later.

Microscopical Examination.

The spinal cord was divided into segments corresponding to the entry of the various nerve-roots, and each segment was stained by Marchi's method. Beginning below and examining segment by segment, no abnormality is seen until the level of upper part of the entry of the 7th dorsal root is reached. At this level a few scattered black dots are seen, not in the entering root, but in the root zone of the postero-external column. These black dots are sparse and much scattered, and the appearance in no way resembles that seen in the next segment above (plate 2, fig. 2).

With the extreme lower fibres of the 6th dorsal root on the right side a mass of black fibres are seen to enter and to spread out in the right posterior root zone (plate 14, fig. 2). The left side shows no black dots whatever, and the specimen is a particularly clean Marchi preparation, without any diffuse black dots so often seen in less successful preparations. Degenerated fibres can be seen to enter the cord by the 6th root on the right side as far up as the entry of the extreme upper fibres of this root.

Throughout this part of the cord opposite the entry of the 5th root the degenerated fibres are seen to lie partly in the posterior horn and partly in the root zone. In the segment opposite the 4th root they have left the posterior horn and lie entirely in the root zone, leaving the entering root and posterior horn free from black. They steadily decrease in number, and at the level of the entry of dorsal 2 would easily be missed had they not been traced from below.

(At this point the cord had been injured so that the upper part of dorsal 2, and the whole of dorsal 1 were unavailable for examination.)

Cervical 8, and all the segments above up to the top of the cord were absolutely free from any signs of degeneration.

Case 4.—Elizabeth V., aged 58. Admitted to Rainhill Asylum on August 23, 1860. Died July 5, 1900.

Summary.

On June 22, 1900, *an imbecile patient developed a profound herpetic eruption over the area in fig.* 4, *corresponding to dorsal* 12. *She died from an undetermined cause thirteen days later.*

Post-mortem *examination revealed no naked-eye disease in the nervous system except that the* 12*th dorsal nerve of the left side could be seen to be swollen in the neighbourhood of the ganglion; but on microscopical examination the following changes were found:*

(*a*) *There was an extreme necrotic lesion in the* 12*th dorsal ganglion of the left side, probably of vascular origin. This caused disintegration of three-fourths of the body of the ganglion.*

(*b*) *The 12th dorsal posterior root was profoundly degenerated on the left side. The 1st lumbar root on the same side also showed a few degenerated fibres.*

(*c*) *Both posterior and anterior primary divisions of the mixed nerve peripheral to the 12th dorsal ganglion on the left side showed profound degenerative changes.*

(*d*) *Degenerated fibres entered the spinal cord on the left side at the level of the 12th dorsal root. This degeneration, which appeared to have not yet reached its height, could be traced up in the posterior columns as high as the 5th cervical segment.*

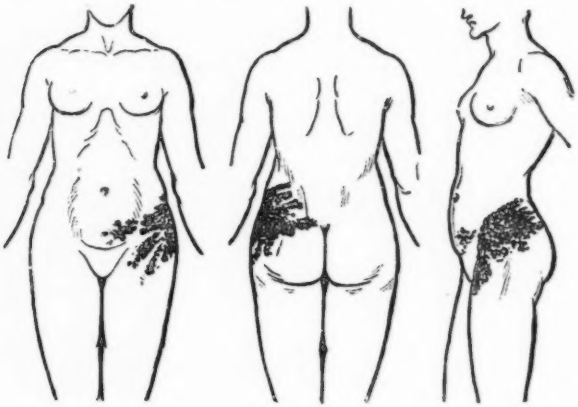

FIG. 4.

To show the distribution of the severe eruption in Case 4.

History.—The record of her forty years of confinement in Rainhill Asylum contains few facts of interest. She was admitted at the age of 18 and was then classified as an imbecile. For the past fifteen years she remained in a state of almost complete dementia, dull, inattentive and unobservant, incapable of entering into conversation or engaging in any employment. She was always untidy in person and dirty in her habits.

Though of delicate constitution and in feeble condition an occasional attack of diarrhœa is the only illness from which she is reported to have suffered.

On June 22, 1900, an herpetic eruption accompanied by marked erythema appeared over the gluteal region of the left side. Fig. 4 is reproduced from some extremely careful drawings, to a scale of one-half life size, by Mr. Marriott, to whom our best thanks are due. At the same time the eruption was seen by one of us and was found to correspond exactly with the drawings.

The eruption had the following distribution. Viewed from behind it was seen to slope over the lateral aspect of the buttock.

There were two or three insignificant, isolated vesicles between the main eruption and the middle line, but the roughly serrated and very irregular inner margin of the concrete portion did not reach quite half way across towards the middle line, and the upper portion lay further outwards than the lower. The upper border was of convex shape and its summit was placed in the flank about one inch (2·5 cm.) above the crest of the ilium. The lower border sloped from behind downwards and forwards, following a line drawn between the posterior-superior spine of the ilium and the great trochanter.

From the lateral aspect a more comprehensive view of the eruption was obtained. The upper border was again situated about one inch (2·5 cm.) above the ilium and ran almost parallel with the crest of that bone. The lower border still sloped down in a straight line and was continued on to the upper part of the thigh in front of the great trochanter. The lower portion of the eruption as seen from the side had a patchy appearance, owing to the presence of islets of healthy skin.

From the front the eruption had a curious distribution difficult to describe. In the hypogastric region was a patch of considerable size connected with the main eruption by a narrow neck; the upper margin of this patch ran transversely slightly below the level of the anterior-superior spines of the iliac bones. The inner border, which dropped more or less vertically downwards, lay from one and a half to two inches (4 to 5 cm.) to the left side of the middle line. Its lower border sloped downwards almost parallel to Poupart's ligament and joined the inner border immediately above the mons veneris.

Lastly, from the lower part of the main eruption two pointed streamers were seen running down the upper part of the front of the thigh parallel to Poupart's ligament. The lower of these two projections consisted almost entirely of erythema.

Along the crest of the ilium the vesicles were largest and most numerous. As the patient could not refrain or be prevented from scratching the eruption it rapidly became worse, and in the course of a few days the entire area had assumed an impetiginous character. Finally pustulation ceased, and healthy granulations formed.

She was kept in bed during the whole of this period, and no change was noted in her general physical condition; but on July 5, thirteen days subsequent to the appearance of the eruption, she suddenly collapsed, her limbs became rigid, and she died in two hours' time.

A specimen of urine collected immediately prior to death was found to be loaded with albumen.

Post-mortem Examination.

The examination was made twenty-two hours after death.

The cadaver was thin, almost emaciated.

Owing to the supervention of acute inflammatory hæmorrhagic

changes, the area of skin over which the herpetic eruption was previously distributed could be defined with the greatest distinctness; the cutis was shed, the surface excoriated, and the whole area had the colour and appearance of raw beef steak. The subcutaneous tissues in this region were also somewhat brawny and œdematous.

No other sign of skin disease was noticed.

Head.—The scalp was thickly covered with hair. With the exception of some increase in density the cranial bones were free from abnormality. The dura mater and its venous sinuses were also healthy. There was some excess of subdural fluid, but no blood or membrane formation. The pia-arachnoid membrane was slightly thicker than normal, but was not unduly adherent. The pial vessels generally were slightly engorged with blood, and the larger arteries at the base of the brain exhibited signs of early atheroma.

The encephalon, though small, was of perfect shape. The convolutions in general were slightly wasted, but entirely free from gross or focal lesion of any sort; their disposition followed a simple type.

The cerebral cortex was rather dark in colour, moderately hyperæmic, and slightly reduced in depth.

The lateral ventricles were somewhat dilated and contained a correspondingly increased amount of fluid.

The condition of the white matter, basal nuclei, &c., calls for no remark. Also the cerebellum, pons, &c., showed no change worth noting.

Spine.—No naked-eye change was observed in the spinal cord or in any of the series of posterior root ganglia and peripheral nerves which were extracted for microscopic examination.

It must here be mentioned that careful examination proved the existence of only eleven pairs of ribs, the lowermost pair being absent. The discovery of this abnormality prevented a mistake in the enumeration of nerves and ganglia which might have occurred if the last pair of ribs had been taken as the only guide.

Thorax.—The chest was of small size and the ribs slender and easily broken, but there were no pleural adhesions and the lungs were in a healthy condition.

The heart muscle appeared to be rather paler and softer than usual, but the organ was of normal size and shape and free from valvular lesion. The aorta also was not obviously atheromatous.

Abdomen.—The peritoneum was in a normal state.

The liver substance was rather soft. The gall-bladder contained about three dozen stones, having an average diameter of 3 mm.; some were smooth and round, while others were faceted. All were of a grayish-yellow colour externally and had a dark brown core.

The spleen was healthy.

The capsule of the kidneys stripped cleanly and the cortex

and medulla were of normal relative depth, but the cortex was pale and the substance in general congested; it was not, however, obviously cirrhotic.

The bladder was moderately distended and contained high-coloured urine.

The alimentary tract and the uterus, &c., were normal.

The following weights were recorded: encephalon, 1,185 grammes; right hemisphere, unstripped, 495 grammes, stripped, 462 grammes; left hemisphere, 500 grammes; cerebellum, pons, and medulla, 160 grammes; right lung, 10¾ oz. (304 grammes); left lung, 9 oz. (254 grammes); heart, 7½ oz. (212 grammes); liver, 35 oz. (990 grammes); spleen, 2 oz. (56 grammes); right kidney, 3½ oz. (99 grammes); left kidney, 3½ oz. (99 grammes).

Microscopic Examination.

(*a*) *Posterior Root Ganglia.*

The ganglia were fixed in 5 per cent. formalin, and after treatment with alcohol were embedded in paraffin and cut serially in longitudinal sections. Some sections were stained with thionin, others by the method of van Gieson, and others with hæmatoxylin alone.

Dorsal 12. *Left.*—This ganglion is the seat of most important changes (plate 8, figs. 3 and 4). We will begin by describing the appearances seen in sections from about the middle of the ganglion, for here the changes are most obvious. The ganglion is so cut that it here appears as an oval body, to which at one end a portion of the posterior root, at the other a portion of the peripheral nerve, are attached, whilst the anterior root is cut in its long axis and lies closely approximated to the less convex side of the oval ganglion.

The whole ganglion is gravely diseased with the exception of about one quarter of the field that lies in close apposition to the anterior root.

The nerve cells in this diseased area are swollen and seem to distend the surrounding capsule.[1] Their nuclei are likewise

[1] In a specimen of a posterior root ganglion which has been fixed in perchloride of mercury and carefully prepared, the nerve-cells will be found to completely fill the investing capsule, and this we may regard as the normal condition; but in specimens fixed in formol, it is our experience that a certain amount of shrinkage occurs, and owing to retraction, the cell is attached to the sheath in places only, its periphery is jagged and spaces are left between it and the capsule. The latter condition we have noted in cells lying in the healthy portion of this ganglion and also in cells of other ganglia from the same case which we have examined for control purposes, and therefore the statement that the cells in the diseased area "seem to distend the surrounding capsule," seems justifiable.

We would mention that we employ formol for the fixation of tissues such as ganglia, because it allows us to display the condition of both nerve-cells and nerve-fibres in the one piece of tissue, which is often desirable. Alcohol and perchloride of mercury, of course, do not possess this advantage.

swollen, and in thionin specimens stain of a uniform blue colour, which is so intense that no nucleolus and no trace of the normal delicate reticular arrangement of the nuclear substance is recognisable. Further they retain their colour so firmly that they are still plainly evident even when decolorisation and differentiation are carried to an extreme extent and most other structures have given up the dye. In van Gieson preparations these nuclei appear of a dark brown colour, and with Ehrlich's hæmatoxylin they assume a uniform deep purple.

This intensely chromophilic condition of the nuclei, in addition to being a most prominent feature of these cells, is also of importance in so far as it affords a clue to the genesis of the ganglionic lesion in cases of herpes zoster, for we have noticed in cases of cerebral embolism or thrombosis in which the subsequent process of softening and disintegration has not proceeded so far as to preclude the possibility of a microscopic examination, that a precisely similar condition of the nerve-cells has existed, and as we shall presently indicate, there are other changes observable in this ganglion which favour the assumption that the primary cause of the lesion is of the nature of an interruption or obliteration of the local vascular supply.

In regard to the bodies of these cells, the substance has a uniformly blurred appearance entirely devoid of definite structure, and the chromophilic particles of Nissl are completely obscured. The particles of pigment normally pertaining to the cell body remain, but they are altered in position; thus in the larger cells this pigment, instead of lying at one end of the cell close to the margin, tends to be arranged in the form of a halo or crescent round the nucleus, and is separated from the periphery on the one hand and from the nucleus on the other by a distinct space. In the van Gieson and hæmatoxylin preparations the substance composing the bodies of these cells has also a blurred look.

Turning next to the condition of the supporting or ground substance of this area, its chief characteristic is that it is blurred; that is to say it stains badly and more or less homogeneously. For instance, in the van Gieson specimens, the red blood-corpuscles are of a grayish-brown colour, whereas in the normal condition they stain a vivid yellow or pale pink; then the nuclear elements which should be present in abundance, stain of a purple colour and be sharply defined, are on the contrary few in number, blurred and indefinite in outline and of a grayish-brown colour. But in spite of the defective stainingthe existence of extravasated red blood-corpuscles can be readily recognised evenly distributed over the whole area and not collected into large masses.

The strands of nerve-fibres passing through the ganglion are plainly seen. They stain a pale pink tint by van Gieson's method, and the primitive sheaths and axis cylinders absorb most of the colour, and the latter are distinctly swollen. All these fibres give the impression that they are undergoing an acute degenerative change.

The periganglionic sheath covering the diseased area does not seem to be specially thickened, nor infiltrated with small round cells, nor are there any hæmorrhages in it.

Coming now to that part of the ganglionic substance lying adjacent to the anterior root which has been alluded to as approximately normal, all the constituent elements stain perfectly well by the various methods. Thus in the nerve-cells a deep-stained nucleolus and a pale nucleus with its delicate reticular network is recognisable, the chromophilic elements of Nissl are clearly defined, and the pigment is normally disposed. The nuclei of the supporting tissue stand out clearly. Here the structure of the walls of the blood-vessels can be plainly defined. The corpuscles contained in these vessels stain normally, but every vessel is engorged with red blood-corpuscles, leucocytes are unduly abundant in their neighbourhood, and in many places extravasations have occurred.

This intense hyperæmia is undoubtedly a pathological condition, and cannot be ascribed to *post-mortem* hypostasis. It resembles the zone of hyperæmia investing an embolic infarct in a kidney.

The remaining serial sections of the ganglion show that the area which has undergone disintegration is sharply circumscribed and involves fully three-quarters of the substance of the body of the ganglion.

It must next be mentioned that the hyperæmic and hœmorrhagic condition described above is not confined to the ganglion, for on examining the attached portion of the peripheral nerve one finds that an extensive pouring out of blood has occurred in the centre of the bundle; lines of effused red blood-corpuscles separate the strands of nerve fibres from one another, and these, along with numbers of engorged blood-vessels, can be followed along it for a distance of several millimeters, continuous with the hæmorrhage in the ganglion. This hæmorrhagic area was noticed with the naked eye before the ganglion was imbedded, and in transverse section had a diameter of about 1 millimeter.

As the parts are so disorganised by hæmorrhage it is difficult to fix on any individual arteriole in this situation, an occlusion of which one might regard as the starting point of the mischief; but entering the distal end of the ganglion and proceeding into the centre of the diseased area already noted, is an artery of fairly large size which is suspicious in appearance, for instead of being congested, as all the other vessels are, it is quite empty, and there is also an excess of leucocytes along its wall.

Lastly, in the portion of the posterior root shown in these sections are more hæmorrhages and engorged vessels, but the anterior root is apparently free from such change, although the large artery which accompanies it is somewhat full of blood.

Dorsal 12, *left; Dorsal* 10 *and* 11, *right and left; Lumbar* 1 *and* 2, *right and left.*—These ganglia are all free from noteworthy alteration.

(b) Posterior Spinal Nerve-roots.

The posterior roots of both sides, from dorsal 11 to lumbar 2 inclusive, were stained by Orr's modification of Marchi's method (osmic acid 2 per cent. 4 parts, acetic acid 1 per cent. 1 part). They were then dissected out into their component twigs and one by one carefully teased and mounted in glycerine. We can confidently recommend this method for displaying degeneration in the spinal roots, because by it the condition of every fibre contained therein can be definitely ascertained.

Dorsal 12. *Left.*—As was expected, this root shows pronounced changes (plate 16, fig. 1).

It enters the cord in four twigs. In the first or uppermost twig fibres showing acute degenerative changes occur abundantly. To begin with, some are swollen and broken up into irregular beads or segments, each segment consisting of a ring of dark brown medullated substance which may be empty or may contain dark or pale round nuclei. On following along such a beaded fibre, one or more blackened clumps of myelin will generally be found in its course. Such fibres are probably in an early stage of degeneration.

In the next place, fibres are present which, although they possess a regular outline, are swollen in some lengths and contracted in others, their groundwork also stains more palely than that of the normal fibre, and in addition, distributed along their course and contained within the outer sheath, blackened globules of altered myelin occur; it is common to see these globules arranged in the form of large round or oval beads, but occasionally they occur as collections of small circular masses. Between these globules the substance of the nerve is in places strewn with coarse, highly refractile, pale brown particles; these are not unlike pigmented bodies, and they give a granular appearance to the portion of the fibre which they occupy. Such fibres as that last described are extremely common and probably represent a more mature stage of degeneration.

The remaining three twigs show similar changes, and an excess of fibrous tissue is manifest in none.

Dorsal 12. *Right.*—One glance at the preparations of this root suffices to prove that they are entirely different from those of the left side.

Careful search under a high power does show an isolated degenerated fibre here and there, but there are not more than ten altogether, and these are of no importance and are commonly found in Marchi preparations when there is no reason to suppose gross disease to be present. The remainder of the fibres are quite normal, their investing ring of myelin running in the form of a straight tube and being interrupted only at the nodes of Ranvier.

Dorsal 11. *Right and left.*—Careful teasing and searching examination only shows a few isolated degenerated fibres, and there is no excess of connective tissue.

Lumbar 1. *Right and left.*—There is again an isolated degenerated fibre here and there.

Lumbar 2. *Right and left.*—No changes of consequence.

Transverse and longitudinal sections of the above roots cut in paraffin afford confirmatory evidence of the above statements.

(c) *Peripheral Nerves.*

The peripheral branches of the 11th and 12th dorsal and the 1st and 2nd lumbar on both sides were stained by Orr's modification of Marchi's method. Some portions were teased and mounted in glycerine, whilst other portions were cut in paraffin both transversely and longitudinally.

Dorsal 12. *Left.*—The nerve is composed of two branches, one small one proceeding posteriorly, and another of larger size passing anteriorly. Both divisions show pronounced and important degenerative changes of an acute nature.

The small posterior division is most severely affected, and very few fibres can be discovered in it which appear to be in a normal condition.

Fibres possessing the following characters, all indicative of degeneration, are extremely common, and go to form the main bulk of the bundle. The normal cylinder of medullated substance is untraceable, and has been replaced by collections of black or dark brown globules; the groundwork stains of a pale-gray colour, and in it are distributed crowds of coarse, circular, refractile dark brown granules which occasionally occur in lines or fusiform clumps; swollen in some places, contracted in others, these fibres have a wavy outline. A few fibres are present in which the myelin sheath is swollen, beaded, and broken up into large oval or circular segments. Following such a fibre along, some clumps of blackened myelin, arranged in the form of beads, can generally be recognised in some parts of its course.

The anterior primary division of this nerve contains considerably more healthy fibres, but at the same time degenerated fibres are numerous. The pale-stained coarsely granular fibres are not so numerous as in the posterior primary division, but the segmented fibres and fibres in which the blackened masses of myelin have run into beads are more frequent.

These changes in the nerve-fibres were all noted in the teased preparations. Examination of sections, both transverse and longitudinal, affords confirmatory evidence of their existence, and shows further that the capillary blood-vessels which course in the endoneurium of these nerves are greatly distended, and have in many instances ruptured, so that the blood has poured out and separated individual nerve-fibres from one another.

After carefully comparing the preparations of this peripheral nerve with those of the corresponding posterior spinal nerve-root, it may be definitely stated that histologically the changes in the

nerve-fibres of both structures are identical in character if different in degree.

Dorsal 12. *Right.*—A fibre here and there shows doubtful signs of degeneration, but on the whole it is healthy, and certainly entirely different from the corresponding nerve of the opposite side.

Dorsal 11. *Left.*—There are a few, perhaps eight or ten, degenerated fibres.

Dorsal 11. *Right.*—A good specimen of a degenerated fibre is not to be found. Along the course of many fibres an isolated black globule is here and there recognised; it is to be noted, however, that these globules never lie in the substance of the fibre, but always on the surface between the primitive and medullary sheaths, and occasionally they occur opposite to the nodes of Ranvier.

Lumbar 1. *Left.*—There is no doubt that a considerable number of fibres are degenerated, but such fibres are infinitely less numerous than they are in the 12th dorsal nerve of the same side. The degeneration is indicated by black beads or globules running along the course of the fibres.

Lumbar 1. *Right.*—In this nerve degenerated fibres are extremely scarce.

(*d*) *Spinal Cord.*

Method of examination.—Stained by Orr's modification of the method of Marchi, and cut transversely in paraffin (plate 12, fig. 1).

Dorsal 12.—Sections from the lower end of the segment show a few scattered degenerated fibres in the dorsal half of the postero-external column of the left side, but no diseased posterior root-fibres on the point of entry. At the middle of the block a few entering degenerated fibres are noticed. At the upper end of the segment a considerable number of fibres have entered and taken up a position along the inner margin of the left posterior cornu in its dorsal two-fifths, and other degenerated fibres are still passing in through Lissauer's tract.

Though the existence of this degeneration is unmistakable and the contrast between the two sides very marked, yet it does not seem to have quite reached maturity, for many fibres, though swollen and otherwise altered, do not give the black reaction with osmic acid, and on that account the diseased field is not so obvious as it probably would have become had a somewhat longer period elapsed between the outbreak of the eruption and death.

Lastly, it must be noted that the substance of the left posterior cornu immediately ventral to the substantia gelatinosa Rolandi is dotted with degenerated fibres. There is no degeneration whatever in any other part of the section, and no evidence of meningitis or any other disease.

Dorsal 11.—Few or no degenerated posterior root-fibres enter at this level.

Hugging the inner margin of the left posterior cornu in its dorsal half, but scarce at the periphery, is a distinct collection of degenerated fibres which from their position we can safely assume entered at dorsal 12. The degenerated fibres seen in the substance of the posterior horn of the left side are still present.

The right posterior column is normal, and the same remark applies to the rest of the field.

Dorsal 10.—The degeneration is beginning to leave the vicinity of the posterior cornu, but still touches it at the innermost part of the field.

Dorsal 9.—The degeneration is removed still further inwards, and has now assumed the form of a thin strip extending from the periphery to a point on the inner margin of the cornu opposite to the column of Clarke.

Dorsal 8 *and* 7.—Similar to dorsal 9.

Dorsal 6.—The degeneration occurs as a faint strip lying nearer to the posterior cornu than to the posterior median septum, and extending from the periphery inwards almost as far as the posterior commissure.

Dorsal 5.—Similar to dorsal 6.

Dorsal 4.—The degeneration is gradually approaching the middle line.

Dorsal 3.—The diseased fibres are becoming difficult to trace. At the periphery they lie about midway between the posterior median septum and the tip of the posterior horn, and from there they extend forwards to the middle of the posterior commissure.

Dorsal 2.—Similar to dorsal 3.

Dorsal 1 *and cervical* 8.—The degeneration is still traceable.

Cervical 7.—Some of these sections are particularly good ones and the degeneration is plainly seen in them; it first follows the septum which divides the column of Goll from the column of Burdach, and then, joining the posterior median septum, it proceeds along it down to the posterior commissure.

In cervical 6 *and* 5 a few blackened fibres can be recognised lying alongside the left postero-lateral septum, but above this the degeneration cannot be followed.

Lumbar 1.—No degenerated fibres enter the posterior columns at this level. Just a few blackened fibres are visible in the dorsal two-thirds of the postero-external column of the left side.

A few degenerated fibres are also seen in lumbar 2 in a like position, but below this level the cord is normal.

Case 5.—William C., aged 5. Out-patient at the London Hospital, September 4, 1897. Died September 18, 1897.

SUMMARY.

The child came to the hospital with the eruption out over the area of the 11*th dorsal segment.*

Fourteen days afterwards he died of exhaustion and slight broncho-pneumonia aided by starvation.

On microscopical examination, the 11th dorsal ganglion was found to be infiltrated with small round cells, and two small hæmorrhagic foci were present. The remaining ganglia were normal.

There was marked degeneration in the fibres of the 11th dorsal posterior root on the left side. A few degenerated fibres were seen in the 12th dorsal root. The remaining roots were normal.

Marked degeneration was seen to enter the cord with the 11th dorsal posterior root of the left side. This degeneration could be traced up as high as the level of entry of the 7th dorsal root, but was then lost.

Degeneration was found in the nerve-fibres on the peripheral side of the ganglion, both just after the posterior primary division has been given off and also a few inches from the patch on the skin.

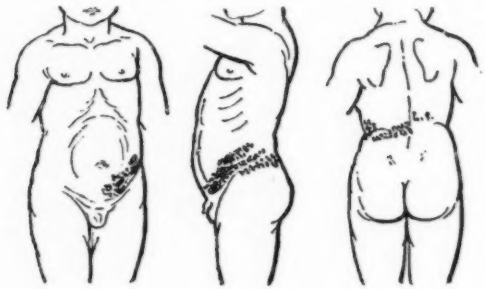

FIG. 5.

To show the distribution of the eruption in Case 5.

The patient came to the receiving room at the London Hospital on September 4, complaining of pain in the abdomen. A few spots of herpes were visible. On September 9 he was again seen, and the herpes was fully developed over the area in fig. 5. The child did not seem ill, but he "lay about." His temperature was 99·6° F. (37·6° C.). No cough. No physical signs in the chest. Nothing could be felt in the abdomen. Bowels opened. Marked swelling of glands in left groin.

On September 18, fourteen days after the eruption, the parents came to say that the child had died in the afternoon. One of us made a *post-mortem* examination with the following result:—

POST-MORTEM EXAMINATION.

Forty-eight hours after death, in cool weather.

The body was much emaciated and there were still unhealed

and scabbed sores over the territory recently occupied by the eruption.

Heart normal.

Lungs normal, except for a little bronchitis and a very few scattered patches of broncho-pneumonia at both bases.

The stomach and small intestine were empty.

Liver, spleen, and kidneys normal.

The brain was normal. Vessels normal.

It is probable that owing to the extreme poverty of the parents the child died of collapse induced by starvation. There was no food in the house, and several of the other children were evidently suffering from hunger. The mother stated that she had had no food in the house for two days, and every particle of furniture had been sold.

Microscopical Examination.

An examination was made of (*a*) a series of posterior root ganglia; (*b*) a series of spinal nerve-roots; (*c*) certain peripheral nerves; (*d*) the spinal cord.

(*a*) *Posterior Root Ganglia.*

An examination was made of the 9th, 10th, 11th, 12th dorsal, and 1st lumbar ganglia of both sides. The ganglia were hardened in 96 per cent. alcohol and embedded in paraffin in such a way that the ganglion of the right and of the left side at each level was contained in the same block. Each block containing two ganglia was cut and stained in strict series. The sections were stained by Nissl's method and counterstained with saffranin or with erythrosin.

Dorsal 11. *Left.*—In transverse serial sections of this ganglion, beginning at the exit of the posterior root, no change is seen at first, except an increase in the small round deeply-staining cells of the interstitial tissue. But as soon as the fibres of the posterior root begin to spread out in the substance of the ganglion, these small round cells increase in number (plate 3, figs. 1 and 2). At one point on the periphery of the ganglion they form an inflammatory focus, in the centre of which a small hæmorrhage is visible. Further along the series, at about the centre of the ganglion, this hæmorrhage increases in size and appears as a straw-coloured mass in the centre of a compact focus of deeply-staining small round cells. This focus extends throughout the ganglion until that part is reached where the peripheral sensory nerve trunk begins to be distinctly formed. Thus, throughout fifty sections passing through the centre of the ganglion a distinct hæmorrhage is visible situated on the periphery of the ganglion just below its sheath, and this hæmorrhage is surrounded by small round cells. Within this area the ganglion cells stain a uniform blue and appear as dark blue undifferentiated masses. Here and there, however,

especially close to the borders of the straw-coloured hæmorrhagic mass, the colourless remains, or "ghosts," of ganglion cells are seen. Even the nucleoli of such cells are only very faintly stained. In addition to this definite focus, small round cells are seen to be in excess throughout this ganglion.

Dorsal 11. *Right.*—No abnormality of any kind in the ganglion cells or interstitial tissue is present in this ganglion.

Dorsal 9, 10, *and* 12, *and Lumbar* 1. *Right and left.*—All normal.

(*b*) *Posterior Nerve-roots.*

The 10th, 11th, and 12th dorsal nerve-roots were stained by Marchi's method, cut transversely and longitudinally, and also carefully teased.

Dorsal 10. *Right and left.*—Normal.

Dorsal 11. *Left.*—Many fibres in this root show undoubted degeneration of the acute type. These fibres are seen in longitudinal section scattered over the field, and are not collected into a bundle.

Dorsal 11. *Right.*—No degeneration.

Dorsal 12. *Left.*—In this root there seem to be a few definitely degenerated fibres. The black dots are jet black, lie in rows, and with a high power can be seen to lie definitely in the substance of the nerve-fibre. There are also a considerable number of leucocytes which stain black, possibly owing to their having picked up products of degeneration.

Dorsal 12. *Right.*—Normal. The longitudinal sections are very clean Marchi's specimens, and show no change resembling that seen in the left nerve-root.

(*c*) *Peripheral Nerves.*

The peripheral nerves connected with the 10th, 11th, and 12th dorsal ganglia were stained by Marchi's method and cut transversely and longitudinally and also teased.

Dorsal 10. *Right and Left.*—Normal.

Dorsal 11. *Left.*—Shortly before the nerve enters the ganglion it is seen to contain a small number of definitely degenerated fibres.

Nearer the periphery, at a short distance from the herpetic patch on the skin, a few distinctly degenerated fibres are seen.

Dorsal 11. *Right.*—No change.

Dorsal 12.—No degeneration in the nerves of either the right or left side.

(*d*) *The Spinal Cord.*

The cord was stained by Marchi's method after hardening in Müller's fluid, and sections were cut of every segment from the 3rd cervical to the 3rd lumbar (plate 11, fig. 1).

Beginning from below upwards, no change is seen until the level of entry of the 11th dorsal root is reached. Here there is obvious and extremely marked degeneration of the fibres that enter from the posterior root on the left side. At the level of entry of the 10th dorsal root the degeneration is seen to the inner side of the posterior horn, but the entering root is free from blackened fibres. At the level of the 7th dorsal root degenerated fibres can still be seen in the postero-external column, but all degeneration disappears at the level of the entry of the 6th dorsal root. The cord above this point is normal.

Thus the degeneration can be traced upwards in the spinal cord for three segments only above the entry of the affected root.

Case 6.—Robert M., aged 35, clerk. Admitted to Rainhill Asylum August 21, 1896. Died February 9, 1897.

SUMMARY.

Admitted to Rainhill Asylum August 21, 1896, *suffering from dementia paralytica.*

December 14, 1896, *he developed herpes zoster over the area in fig.* 6, *corresponding to the* 3*rd cervical.*

He died from seizures of dementia paralytica on February 9, 1897, *fifty-seven days after the appearance of the eruption.*

On microscopical examination the following changes were found:—

(*a*) *Posterior root ganglia.—The* 3*rd cervical ganglion of the left side was severely diseased. A considerable segment was entirely denuded of nerve-cells and nerve-fibres, and the ganglionic sheath investing the affected area was thickened.*

(*b*) *Posterior spinal roots.—The* 3*rd cervical root of the left side showed marked sclerosis and signs of an acute degeneration, the products of which were being absorbed. Some bundles of the* 4*th*

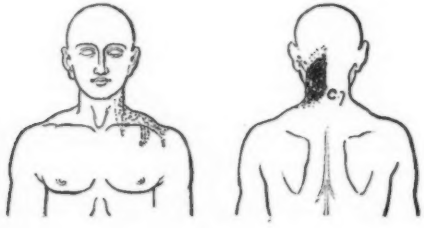

FIG. 6.

To show the distribution of the eruption in Case 6.

root on the left side also seemed to have undergone change, but this was a less certain change than that of the 3rd root.

(c) *Peripheral nerves.—The trunk and branches of the 3rd, and to a less extent of the 4th cervical nerve, were partially sclerosed, the change being more marked at the periphery than in the neighbourhood of the ganglion.*

(d) *Spinal cord and medulla oblongata.—The entering fibres of the 3rd cervical posterior root on the left side were markedly degenerated, and a few degenerated fibres seemed to enter the cord at the level of the 4th and possibly the 2nd cervical root on the left side. These fibres collected in a systematised field of degeneration which could be traced up to the nucleus cuneatus of the same side.*

Clinical. — No history obtainable. On admission he was extremely demented. The pupils were contracted (3 mm.) immobile and the margins uneven. Deep and superficial reflexes much exaggerated. Muscles in general wasted and paretic; locomotion impossible. Tongue could not be protruded and was very tremulous. Articulatory trouble so marked that he could not even pronounce his own name. Pulse 86, regular. Heart, lungs, genito-urinary and alimentary systems normal.

December 14, 1896. Developed severe herpes on the back of the neck on the left side over the area indicated in fig. 6. The vesicles soon became confluent, and the hair covering the portion of scalp affected was matted together by exudation. The eruption was accompanied by no rise of temperature or alteration in his general physical or mental condition.

December 28. The skin of the margin of the eruption was beginning to look healthy, but at the centre there was still marked scabbing and reddening; the hair of the affected scalp was falling out.

On January 17, 1897, he had three seizures, and it was noted that he had fallen off greatly in weight.

On January 27 he had five more seizures, on February 2 another, on February 9 three more, and from the last of these he did not rally.

Interval between the date of the herpetic eruption and the date of death, fifty-seven days.

Post-mortem Examination.

The examination was made thirteen hours after death in cold weather. Body thin, almost emaciated; skeletal and muscular development poor; no localised muscular atrophy, and no contractures.

In the portion where the herpetic eruption had been most intense, the skin was white and smooth, and there were some scabs; there was also a bald patch of occipital scalp along the lower border on the left side.

Calvaria of average size, slightly thickened and increased in density; dural sinuses partly filled with *post-mortem* blood clot; dura mater slack anteriorly, no localised thickening or unusual adhesions to bone or arachnoid. A marked excess of clear watery cerebro-spinal fluid. The encephalon weighed 1,135 grammes.

The main cerebral vessels showed general thickening, but there was no calcification.

The arachnoid presented the universal opacity and thickening characteristic of advanced general paralysis. The pia mater was markedly thickened and slightly anæmic. It was very adherent, and decortication attended its removal; this was most pronounced over the central convolutions.

The brain was a small one, but the hemispheres were equal and the segments proportionately developed. The convolutions were rather complexly arranged, but were generally wasted, the atrophy being most noticeable frontally. The sulci were all wide and shallow.

The right hemisphere, with its membranes, weighed 487 grammes, the left 497 grammes.

The cortex cerebri was dark in colour, firm, slightly anæmic, reduced in depth and indistinctly striated.

The white substance was of healthy colour and consistence, and normal vascularity. The lateral ventricles were enlarged, and contained an excess of fluid, and the ependyma was slightly granular.

The basal nuclei were free from focal lesion.

The corpus callosum and other commissures were healthy.

The cerebellum weighed 137 grammes, its cortex was dark and thin, and its general consistence firm.

In the pons there was no noteworthy change.

The gray and white tissues of the medulla oblongata were healthy to the naked eye, but the ependyma of the fourth ventricle was very thick and granular.

The pons and medulla together weighed 30 grammes.

The cranial nerves were healthy to the naked eye.

Adhesions of an abnormal character existed between the dura and arachnoid all along the dorsal aspect of the spinal cord; the pia-arachnoid was unusually opaque, and there was an excess of cerebrospinal fluid.

The spinal nerve-roots and posterior root ganglia in the cervical region of either side presented no gross macroscopic change.

The superior and middle cervical sympathetic ganglia also appeared the same on both sides to the naked eye.

Nine ribs on the right side and seven on the left showed old fractures. Those on the right side were the 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 9th, and 10th; and of these the 5th, 6th, 7th, 9th, and 10th were fractured in two places. All these ribs were broken at points between one and two inches from the costo-chondral articulation, and in the case of those which were

broken twice, the second fracture was situated some three inches or more from that joint. The broken ribs on the left side were the 4th, 5th, 6th, 7th, 8th, 9th and 10th; several of these were fractured in two places, and the break in every case lay between one and three inches from the costo-chondral joint. All these fractures were of old-standing, and in the case of the majority firm union had occurred, but in some (more particularly the lower ones) slight movement could be obtained at the site of the fracture. There was considerable displacement in some instances, and around all much callus had been thrown out. They were probably all of the same age (about six months). The right pleural cavity was obliterated by old fibrous adhesions; the left was free.

The general colour of the lungs was dark and a few broncho-pneumonic patches were found in both.

The pericardium contained a normal amount of clear fluid.

The heart was of rather small size and weighed 8 oz. (226 grammes), its muscle was dark and firm. Little clot was present in its chambers, there was no organic disease of valves or aorta.

Peritoneum healthy.

The liver weighed 39 ozs. (1,103 grammes). Some old adhesions existed between the upper surface of the right lobe and the diaphragm. Its substance was dark and firm on section and the gall bladder was healthy.

Spleen dark and firm; weight 3 ozs. (84 grammes).

The capsules of the kidneys stripped cleanly, the substance was dark and firm, and the organs were small. The right kidney weighed 3 ozs. (84 grammes), the left 3½ ozs. (99 grammes).

The suprarenal glands, stomach, pancreas, intestines and bladder were normal.

On the foreskin of the penis the existence of some scars pointed to previous syphilitic infection, and there was excess of fibrous tissue in both testicles.

Microscopic Examination.

A microscopic examination was made of (*a*) a series of posterior root ganglia, (*b*) a series of spinal nerve-roots, (*c*) a series of peripheral spinal nerves, (*d*) the superior cervical sympathetic ganglia, (*e*) the spinal cord and medulla oblongata.

(*a*) *Posterior Root Ganglia.*

The posterior root ganglia examined were the 2nd, 3rd, 4th, 5th and 6th cervical of both sides.

Cervical 3. *Left.*—The ganglion was hardened in formalin 4 per cent., and without further preparation fixed in gum on a freezing microtome, and cut transversely but not serially. Numerous sections were stained (*a*) for the display of nerve-cells by the method of Nissl, (*b*) for the display of connective tissues with Mallory's hæmatoxylin, (*c*) for the display of nerve-

fibres by an original method with osmic acid and hæmatoxylin, which may be briefly described as follows :—

(1) Warm for a few minutes in osmic acid 1 per cent. until sections brown.

(2) Wash thoroughly in water.

(3) Warm for a few minutes in the solution of hæmatoxylin employed in the Weigert-Pal method.

(4) Wash in water and decolorise by method of Pal.

(5) Counterstain with Held's solution of erythrosin.

The majority of the sections, however stained, show important alterations (plate 5).

On that side of the ganglion furthest away from the anterior root is an extensive diseased field of crescent shape, the convexity of the crescent being represented by the circumferential margin of the ganglion, round about two-thirds of which it stretches. This focus extends inwards for about 1·275 mm., so as to invade from a quarter to one-third of the sectional field of the ganglion. The affected substance is composed of small round cells arranged in masses and in lines, of fields of coarse fibrous tissue and of newly-formed blood-vessels, and it is remarkable that every single nerve-cell and nerve-fibre has disappeared from this area. The line of demarcation between the healthy and diseased fields, under a low power of the microscope, looks abrupt and definite, but under a higher power one can make out that some of the nerve-cells on the border line are degenerated.

The remainder of the substance of the ganglion is healthy. But that part of the sheath of the ganglion which covers the affected area is greatly thickened, its component lamellæ are widely separated from one another, infiltrated by numbers of small round cells, and rich in thickened and congested blood-vessels. The anterior root as it passes round the ganglion is normal.

It is unfortunate that this ganglion was not cut in series so that the seat of maximum affection might be correctly localised, but as the sections toward either end of the ganglion are less affected than the central ones it appears that the diseased focus is situated mainly in the median longitude of the body.

Cervical 3. *Right.*—Stained and cut in the same way as the ganglion just described. It shows no change and differs fundamentally from the corresponding ganglion of the opposite side.

Cervical 2, 4, 5 *and* 6. *Right and left.*—Show no change.

(*b*) *Spinal Nerve-roots.*

Both anterior and posterior roots were stained by Marchi's method, and cut longitudinally and transversely.

Cervical 3. *Left.*—Where the roots pierce the dura, three bundles of the sensory root are undergoing acute degeneration, or have undergone degeneration, and the products are already

partly absorbed. For these bundles have a hazy look, their component fibres are blurred and swollen, and the fat droplets are gray in colour. In the neighbourhood of these three bundles are others which are to some extent sclerosed.

In sections nearer to the ganglion where the sensory and motor roots can be more readily differentiated, about one-third of the fibres of the sensory root have disappeared, and are replaced by fibrous tissue. These diseased bundles are clumped together at one end of the section (plate 16, fig. 2).

The anterior root is perfectly healthy and shows none of these changes.

Cervical 3. *Right.*—This root shows no change.

Cervical 4. *Left.*– There is slight apparent thickening of the sheath over one bundle, but this may be due to the obliquity of the section. If there is any change it is extremely slight.

Cervical 4. *Right.*—Normal.

Cervical 2, 5 and 6. *Right and left.*—Show no change.

(*c*) *Conjoint Peripheral Nerves.*

Stained by Marchi's method, and cut transversely and longitudinally.

Cervical 3. *Left.*—This nerve presents a very striking appearance. In the more peripheral sections when the nerve is split up into numbers of small bundles there is hardly one that is not markedly sclerosed. In sections nearer the ganglion where the bundles are large the sclerosis is less evident.

Cervical 3. *Right.*—This nerve shows no change.

Cervical 4. *Left.*—The sensory bundles close up to the ganglion show scattered sclerosis. Towards the periphery three bundles appear to be absolutely sclerosed.

Cervical 4. *Right.*—No change.

Cervical 2, 5 *and* 6. *Right and left.*—Normal.

Great occipital nerve. Left.—Stained by Marchi's method. No individual bundle possesses quite its full complement of fibres, and in three bundles in particular there is a great falling out of nerve-fibres and a replacement by fibro-cellular tissue. There is practically no acute degeneration, and the perineurium looks healthy. The blood-vessels have thickened walls.

Great occipital nerve. Right.—There is absolutely no acute degeneration. No patches of sclerosis are seen as on left side.

Small occipital nerve. Right and left.—No obvious degenerative alteration.

(*d*) *Superior Cervical Sympathetic Ganglia.*

Right and left.—These ganglia were hardened in formalin 4 per cent., and sections were stained—(1) by the method of Nissl, (2) with Mallory's hæmatoxylin, (3) with osmic acid and hæmatoxylin, as those of the 3rd cervical posterior root ganglia. This method displays the non-medullated fibres well, but by none of the processes were morbid changes discovered.

(e) Spinal Cord and Medulla Oblongata.

Stained by the method of Marchi (plate 10, fig. 2).

Cervical 3.—Both transverse and longitudinal sections were cut at the level of entry of the 3rd cervical roots.

The extraspinal portion of the left posterior root as it appears in these sections is almost entirely free from acute degeneration, but is sclerosed. No acute degeneration can be seen in Lissauer's root zone. But immediately after entering the cord the posterior root-fibres show typical acute degeneration which can be clearly made out in both longitudinal and transverse sections. There is further, a field of acutely degenerated fibres in the left postero-external column, which on transverse section is seen to hug the posterior cornu. These diseased fibres are most numerous opposite the substantia gelatinosa Rolandi, whence the field tapers inwards and ends about two-thirds of the way along the posterior horn.

In the centre of the gray substance of the left posterior cornu is another isolated small collection of degenerated fibres.

Cervical 2.—*Transverse and longitudinal sections.*—In the outer part of the left postero-external column the above-mentioned strip of degeneration is very clearly seen. It is again widest in its most dorsally situated part, and tapers inwards as before, but it is not now so closely applied to the margin of the cornu.

Fibres of large and small size are commingled in the degenerated area. In the intraspinal but not in the extraspinal portion of the entering left posterior root are a few acutely degenerated fibres. Indications of degeneration are again visible in the gray substance of the left posterior cornu.

There are a few degenerated fibres in the lateral columns on both sides, such as are so commonly found in cases of dementia paralytica.

The pia-arachnoid is perhaps a little thick and more cellular than normal, but there is no localised meningitis. The arteries in places show signs of arteritis.

Cervical 1.—In the lateral one-third or one-fourth of the left funiculus cuneatus is a prominent field of degenerated fibres, extending from the nucleus cuneatus, which is here forming, to the periphery. These fibres are more numerous in the ventral than in the dorsal portion. On a rough estimate there are about 500 diseased fibres, and they are mainly of small calibre.

Medulla Oblongata.—Immediately above the pyramidal decussation there is a well-marked collection of degenerated fibres in the outer one-third of the left funiculus cuneatus, and this is continuous with a thin line of diseased fibres, which skirts the periphery of that column. A few degenerated fibres are also visible in the cuneate nucleus.

Medulla oblongata. Level of lower end of great olive.—The degenerated fibres lie in that part of the funiculus cuneatus which

is nearest to the sensory root of the fifth nerve and the substantia gelatinosa Rolandi. Their number has diminished greatly

Medulla oblongata. At lower end of fourth ventricle.—The degenerated fibres can still be traced in the lateral portion of the funiculus cuneatus, and some diseased fibres are seen streaming into the so-called external cuneate nucleus which is appearing at this level. A band of external arciform fibres lies between the degeneration and the surface; these fibres and likewise the internal arciform fibres are free from degeneration.

Medulla oblongata. Through middle of great olive.—Round the left nucleus cuneatus on its dorso-lateral and ventral aspects are a few scattered degenerated fibres. A few black dots are also present within the nucleus.

It is impossible, owing to the method of staining, to say anything definite concerning changes in the nerve-cells of the nucleus.

Medulla oblongata. Through upper end of nucleus cuneatus.—At the periphery fringing the left nucleus cuneatus just a few degenerated fibres can be defined, and there are also a few black dots in the substance of the nucleus.

Higher than this the degeneration is not traceable.

Spinal Cord below the entry of the affected Root.

Cervical 4.—There are just a few scattered degenerated fibres of small calibre in the dorsal and lateral part of Burdach's column on the left side, and a very few degenerated posterior root-fibres seem to be entering at this level.

Cervical 5.—A very few black dots are seen along the inner margin of the left posterior cornu. These may be descending collaterals, but it is difficult, owing to their small number and scattered appearance, to be sure if they can bear this interpretation.

Cervical 6.—No change in posterior columns.

Cervical 7, 8 *and Dorsal* 1.—No change in the posterior columns.

All the sections of medulla oblongata and spinal cord show disseminated degenerated fibres in both pyramidal tracts associated with the dementia paralytica from which this patient suffered.

Case 7.—Frank C., aged 32. Admitted to Guy's Hospital (Dr. Hale White), April, 1895. Died September 2, 1895.

SUMMARY.

A man of 32 *suffered for a year with progressive anæmia and enlargement of the spleen, for which he took arsenic over a considerable period. On admission to Guy's Hospital both spleen and*

liver were found to be enlarged, and there was some enlargement of the lymphatic glands. The blood showed marked increase of polynuclear leucocytes with eosin-staining granules.

On May 29, 1895, he developed a profound eruption of herpes zoster over the area in fig. 7 corresponding to the 2nd dorsal.

His general condition became gradually worse, and he died on September 2, 1895, ninety-six days after the eruption first began to appear.

Post-mortem examination showed marked general enlargement of the spleen. The liver was also enlarged and contained collections of leucocytes throughout its substance. The marrow of the long bones was replaced by a yellow jelly-like mass.

The site of the previous herpetic eruption was extremely clearly marked out by brown pigmented patches.

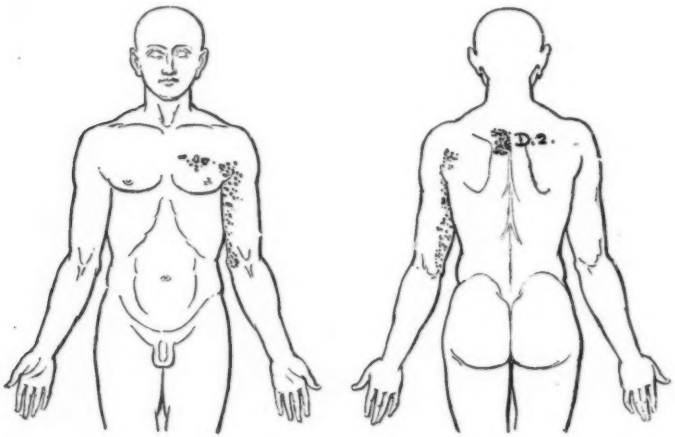

FIG. 7.

To show the distribution of the eruption in Case 7.

On microscopical examination the following changes were found:—

(*a*) *Posterior root ganglia.—The 2nd dorsal ganglion of the left side showed a distinct local lesion destroying the nerve-cells and fibres over a considerable extent of the body.*

(*b*) *Posterior spinal nerve-roots.—In the 2nd dorsal posterior root of the left side several nerve fasciculi were manifestly diseased; with the method of Marchi these bundles presented on the whole a pale sclerosed aspect, but they also contained the partially-absorbed remnants of an acute degenerative process.*

In the 3rd dorsal root of the same side a few degenerated fibres could be recognised.

(*c*) *Peripheral nerves.—Some bundles of the left 2nd dorsal conjoint trunk were altered similarly to the 2nd dorsal posterior root. There were no obvious changes in the 3rd dorsal nerve.*

(*d*) *Spinal cord.—Many nerve-fibres which entered from the 2nd dorsal posterior root of the left side and a few fibres from the 1st dorsal root were acutely degenerated, and these fibres collected to form a systemic field of degeneration which could be followed up as far as the left nucleus cuneatus.*

History.—In April, 1894, he began to suffer from attacks of pain in the left side with cold sweats at night. In June his abdomen and feet began to swell. In November the extraction of two teeth was followed by profuse bleeding lasting forty-six hours.

He served in the army, but for the last three years has been a general labourer.

He took arsenic from August, 1894, to March, 1895, in the Croydon Hospital.

There is no history of syphilis.

On admission, he was somewhat wasted. The anæmia was not very marked.

The abdomen was distended, and on palpation a splenic tumour could be felt occupying the left hypochondriac and lumbar regions. Its surface was smooth and its edge even. The tumour edge began at the ensiform cartilage and extended downwards to a point $1\frac{1}{2}$ inches (3·75 cm.) to the right of the umbilicus and reached below to within 1 inch (2·5 cm.) of the iliac crest.

The liver was enlarged, and the edge could be felt below the costal margin. Some ascites was present.

The inguinal, axillary, and right posterior cervical glands were enlarged.

Heart normal, except that a systolic bruit was heard at the apex. Examination of the blood showed that the white corpuscles were much increased. The majority of the white corpuscles were larger than usual, containing two or three neucleoli, and with granules that stained with eosin.

Urine was normal.

Progress of the case.—Spleen varied in size but did not greatly increase. Temperature was raised each night.

May 29. Herpes zoster appeared over the area in fig. **7.** The vesicles appeared on an inflamed base, enlarged, and became confluent, forming bullæ. Extremely marked pain was present which continued on and off until August. The vesicles healed, but the whole area on which the eruption had appeared was covered by dark brown pigmented scars, probably due to the fact that he had been taking arsenic until within a fortnight of the eruption.

The patient became extremely thin, and he began to have attacks of diarrhœa. The temperature was permanently raised, with nightly exacerbations. He became gradually weaker, and died on September 2, 1895, ninety-six days after the appearance of the eruption.

Post-mortem Examination.

Made twenty-four hours after death. The position of the herpetic eruption was extremely well marked out by dark stains on the skin.

Both pleural cavities contained fluid. The upper part of both lungs was emphysematous and œdematous.

Spleen weighed 84 oz. (2·37 kgm.), and was soft and smooth. It contained a large infarct.

Liver weighed 85 oz. (2·4 kgm.). Throughout its substance were collections of leucocytes.

Heart normal.

The femur contained a jelly-like yellow mass replacing the absorbed cancellous tissue. The marrow of the sternum was very pale.

The nervous system showed no naked-eye change, and was preserved for microscopic examination.

Microscopical Examination.

A microscopic examination was made of:—(*a*) a series of posterior spinal root ganglia, (*b*) a series of spinal nerve-roots, (*c*) a series of peripheral nerves, (*d*) the spinal cord.

(*a*) *Posterior Root Ganglia.*

The following ganglia were examined:—The 2nd, 3rd, 4th, 6th, 7th and 8th cervical, and the 1st, 2nd, 3rd, 4th and 5th dorsal, all of the left side.

The method of examination employed in the case of each ganglion was as follows:—The entire ganglion along with the attached spinal nerve-roots and a portion of the conjoint peripheral nerve-trunk was stained *en bloc* by the method of Marchi. After imbedding in celloidin, serial sections were made in the longitudinal direction, and every alternate section of the series was mounted.

Dorsal 2.—Of the twenty-three sections mounted the first six show remarkable changes in the sheath and body of the ganglion (plate 7). The sheath is thickened and blurred all round, it is infiltrated by small round cells, and its contained blood-vessels are extremely congested with red blood corpuscles. Within the sheath in the substance of the ganglion there is not a single nerve-cell or nerve-fibre of any kind to be made out, the

place which they should occupy being entirely filled up by a collection of foreign tissue which does not stain with osmic acid, and in which lie numerous collections of brown coarsely-granular amorphous pigment and many congested blood-capillaries.

In the next two or three sections the ganglionic field exhibits a transition stage between a healthy and a diseased condition, that is to say, some portions of the field are occupied by morbid tissue as above described, others by normally arranged collections of nerve-fibres and nerve-cells. With regard to the structure of these nerve-cells nothing definite can be stated, as the method of Marchi is not adapted for displaying them, but of the bundles of nerve-fibres a considerable number are acutely degenerated, with rows of irregular-shaped black masses running along the course of these fibres; other bundles seem to be to a large extent sclerosed.

In the remaining sections the ganglion, so far as can be judged from the method of Marchi, presents a healthy appearance, nerve-cells and nerve-fibres are abundant, and there is a complete absence of any destructive change.

Thus over a certain area of the ganglion the sheath is thickened and diseased, and the ganglionic substance subjacent to this portion of altered sheath is destroyed to about one-fourth of the depth of the whole ganglion.

Dorsal 1.—The blood-vessels in the connective tissue in the environment of the ganglion show marked congestion, but this is a common appearance not to be regarded as pathological. The nerve-cells and nerve-fibres seem to be normally represented, and with the exception of one or two minute pale-stained granular foci of doubtful significance no change is manifest.

Cervical 8, 7, 6, 4, 3 *and* 2.—The ganglia show no noteworthy change.

Dorsal 3, 4 *and* 5.—The ganglia show no noteworthy change.

(*b*) *Spinal Nerve-roots, Anterior and Posterior.*

Dorsal 2.—The major portion of the posterior root appears to be healthy, or only shows an acutely degenerated fibre here and there, but there are several bundles which exhibit changes of a pronounced character. Most noticeable is a deficiency in number of healthy fibres and a substitution for them of unstained fibro-cellular tissue; in short, a form of sclerosis. Scattered over the same field are rows of irregular-shaped blackened fatty particles, indicating nerve-fibres actually undergoing disintegration, and in the same field an abnormal number of congested capillaries are distinguishable.

A continuity between these diseased bundles and the focal lesion described under the heading of the second dorsal ganglion can be traced.

The anterior root is not degenerated.

Dorsal 1.—Some few nerve-fibres in the posterior root seem to

be undergoing degeneration, but the change is by no means a striking one.

The anterior root is normal.

Cervical 8, 7, 6, 4, 3 *and* 2.—All normal.

Dorsal 3, 4 *and* 5.—All normal.

(*c*) *Conjoint Peripheral Nerve-trunks.*

Dorsal 2.—Examined near the ganglion. The major portion of the conjoint trunk seems to be healthy, but there are one or two bundles which are in large measure sclerosed, and also contain a few acutely degenerated fibres and many congested capillaries. There are likewise degenerated fibres in considerable numbers in what seems to be the posterior primary division of the nerve.

Dorsal 1.—There are a few fibres visible which seem to be degenerated, but the evidence of degeneration is not pronounced.

Cervical 8, 7, 6, 4, 3 *and* 2.—All normal.

Dorsal 3, 4 *and* 5.—All normal.

(*d*) *Spinal Cord.*

Method of examination.—Portions of the cord were taken from the levels of entry of all nerve-roots from the 1st sacral to the 1st cervical inclusive. These blocks were stained by the method of Marchi and cut transversely and in some cases longitudinally as well (plate 10, fig. 1).

Dorsal 2.—In transverse section degenerated fibres are seen to enter in the left posterior root, and a well-defined strip of diseased fibres is seen hugging the inner margin of the left posterior cornu. This field of degeneration extends from the periphery to a point about midway along the cornu, it tapers off internally, is thickest at about its middle, and, in that part of it situated next the periphery, the degenerated entering root-fibres are cut longitudinally or obliquely.

This can hardly be called a "mass degeneration," because the individual diseased fibres are all separated from one another by interposed healthy tubules, and on a rough count their total number only just exceeds 300.

It is to be further noted that in the centre of the gray substance of the left posterior horn, immediately ventral to the substantia gelatinosa, a few diseased fibres of small calibre are seen cut transversely.

The postero-external column of the right side is normal, and all other columns are also free from degeneration. Special attention must be drawn to the fact that all the degeneration in the spinal cord is essentially of an acute nature, and that there is no indication whatever of post-degenerative sclerosis in any part of the intraspinal course of the degenerated posterior root-fibres.

This is an important fact, because, as has already been mentioned, examination of the affected posterior root prior to its entry reveals the predominance of a sclerotic over an acute degenerative change.

Dorsal 1.—Transverse sections opposite the level of entry of the posterior roots show that the field of degeneration in the left postero-external column noted in dorsal 2 is translated slightly inwards, so that while the inner tapering portion still hugs the posterior cornu, the more dorsal thicker portion is separated from the cornu by an appreciable interval. Again, a few acutely degenerated fibres are seen entering in the left posterior root, and there also appears to be a slight increase in the numerical strength of the fibres in the degenerated field. Again, also, a few degenerated blackened fibres are visible in the gray substance of the posterior cornu just ventral to the gelatinous substance.

Longitudinal sections at this level well display the degenerated fibres which have entered at dorsal 2, and likewise confirm the point above mentioned, that a few diseased fibres are entering from the 1st dorsal root of the left side.

Cervical 8.—The degenerated fibres are scattered in comma form in the left postero-external column. The head of the comma is at the periphery, the tail touches the posterior horn at a point rather more than half way down its inner margin, and the convexity is directed towards the middle line. A space is thus left between the area of degeneration and the dorsal half of the posterior cornu, which contains practically no degenerated fibres.

Cervical 7.—The field of degeneration maintains its comma form but is placed still further inwards; the head of the comma lies in the inner half of the postero-external column at the periphery, its convexity touches the intercolumnar septum, and the tail gradually tapering off just reaches the inner margin of the neck of the posterior cornu not far behind the posterior commissure.

Cervical 6.—The field containing degenerated fibres is becoming cuneiform. It is situated mainly in the inner and posterior angle of the postero-external column. The tail of the above-mentioned comma is disappearing and degenerated fibres no longer touch the posterior horn.

Cervical 5.—The degenerated fibres are clumped together in a wedge-shaped area at the posterior and inner angle of the postero-external column.

Owing to a gradual disappearance of degenerated fibres which has been occurring all the way up the cervical region, the total number of diseased fibres at this level is considerably diminished when compared with the sections at the level of dorsal 1.

Cervical 4.—The degenerated fibres lie in a similar position to that they occupied at cervical 5, but the field has lost its wedge shape, and is beginning to retreat from the periphery.

Cervical 3.—The degeneration is still further removed from the periphery.

Cervical 2.—The degenerated fibres are very sparsely scattered at this level, and indeed difficult to locate at all, but a careful examination leaves no doubt of the existence of a few, and these from their position are evidently making for the head of the nucleus of the left funiculus cuneatus.

Cervical 1.—Similar to cervical 2.

In sections higher up, showing the cuneate nuclei, it can just be made out that degenerated fibres enter the inner side of that body.

Case 8.—Elizabeth B., aged 76. Admitted to Marylebone Infirmary (Mr. Lunn), January, 1895. Died February 18, 1896.

SUMMARY.

Admitted with right hemiplegia and in a demented condition. November, 1895, *had another "fit."*

November 7, 1895, *developed an acute attack of zoster over the area in fig.* 8.

She died from pneumonia on February 18, 1896, 103 *days after the attack of zoster.*

On post-mortem examination the left cortex showed two areas within which the whole cerebral substance had been destroyed. The outer surface of the right hemisphere of the cerebellum showed a similar area of softening.

On microscopical examination the following changes were found :—

(*a*) *Posterior root ganglia.—The* 12*th dorsal ganglion of the right side showed a pronounced focal lesion destroying nerve-cells and nerve-fibres over a considerable extent of the body.*

(*b*) *Posterior spinal nerve-roots.—In the* 12*th dorsal root of the right side a number of fasciculi exhibited manifest changes. Nerve tubules had disappeared and were replaced by fibro-cellular elements and collections of partially-absorbed degenerative products.*

(*c*) *Peripheral nerves.—The* 12*th dorsal conjoint trunk of the right side was similarly affected to the above-mentioned posterior root.*

(*d*) *Spinal cord.—As soon as the fibres of the* 12*th dorsal posterior root of the right side entered the cord, they showed the typical staining reaction of acute degeneration, and pursuing the recognised course of a root lesion, they could be followed along in the posterior columns as far up as the* 7*th cervical segment.*

Degeneration was also seen in the right lateral pyramidal and in the left direct pyramidal tracts, and a few degenerated fibres in the left lateral pyramid, due to the cerebral softening and connected in no way with the herpetic lesion.

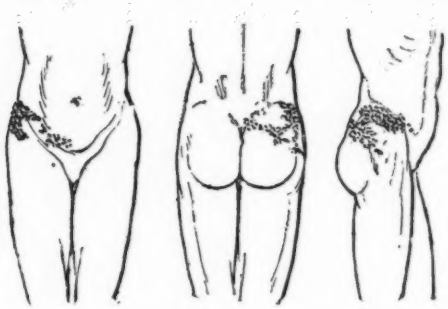

FIG. 8.

To show the distribution of the eruption in Case 8.

No history of her general condition could be obtained beyond the fact that she had long been an inmate of the Workhouse, and that she was admitted to the Infirmary in January, 1895, with right hemiplegia. She remained in a demented condition, passing urine and fæces under her, until November, 1895, when she had another "fit," in which the left half of the face and the left arm were convulsed.

On November 7, 1895, she developed an acute attack of herpes over the area in fig. 8.

At this time her condition was as follows:—She could not name any object at sight, but had no sign of motor aphasia. Right arm and right leg were absolutely paralysed, and both were in a condition of extreme contracture. Sensation to pain was everywhere present. The right knee-jerk could not be obtained, but this was possibly due to marked changes in the joint. Left knee-jerk was just obtained. Both plantar reflexes were brisk, the right more so than the left. The right ankle was ankylosed, and thus could not be examined for ankle clonus. No ptosis, ocular paralysis or nystagmus were present. Pupils reacted to light and accommodation. Some weakness of movement was visible about the lower part of the right half of the face. She could only protrude the tongue to a slight extent. Incontinence of urine and fæces.

All the arteries were extremely thickened and degenerated, but otherwise there was no noteworthy change in the circulatory or respiratory systems.

She died of pneumonia on February 18, 1896, 103 days after the attack of herpes zoster began.

POST-MORTEM EXAMINATION.

Made forty hours after death in bitterly cold weather. The post-mortem room was at the external temperature.

Rigor mortis well marked.

Well marked dark brown scaly scars were present over the area that had been occupied by the eruption.

No bedsores or other changes in the skin.

Some turbid yellow fluid was present in the left half of the chest, and the parietal pleura on the left side was covered with flakey yellow lymph. The upper lobe of the left lung was solid, and the lower lobe airless and collapsed. The right lung was universally adherent and showed signs of general bronchitis.

The heart was normal, except that its walls were soft and fatty. The aorta was somewhat atheromatous.

Peritoneum normal. Liver somewhat fatty. Capsule of the spleen much thickened. Kidneys were slightly granular. Bladder normal.

Nervous system.—The spinal cord was beautifully firm throughout, and showed no gross anatomical change. The brain weighed 1,105 grammes; when separated the right hemisphere weighed 509 grammes, (stripped 481 grammes), the left hemisphere 424 grammes (stripped 396 grammes), the cerebellum 95 grammes.

The vessels were exceedingly tough and degenerated.

The brain was much shrunken and wasted, and the dura mater lay in folds.

On the outer aspect of the left cerebral hemisphere were two isolated areas, where the cortex and subjacent white substance had been destroyed for a long time owing to thrombotic arterial occlusion; both were situated in the posterior segment of the hemisphere. The larger patch, measuring about 4 cm. in its maximum vertical by 5 cm. in its greatest horizontal diameter, extended transversely from the posterior end of the sylvian fissure in front to within 1 cm. of the posterior margin of the occipital lobe behind, and vertically from 1 cm. below the horizontal limb of the intraparietal sulcus above to the posterior extremity of the 2nd temporal sulcus below. The entire cortex and the subjacent white substance down even to the ependyma of the posterior horn of the lateral ventricle, was destroyed over practically the whole angular and posterior parietal gyri and over parts of the supramarginal, occipito-parietal and occipito-temporal annectant gyri.

The smaller patch, measuring about 3 cm. in the vertical direction by 1·5 cm. in the horizontal, had its centre at the upper end of the ascending limb of the intraparietal sulcus and involved adjacent parts of the supramarginal and superior parietal gyri. The ascending parietal convolution had escaped.

On the inner aspect of the same hemisphere was another narrow patch of old-standing softening, beginning in front at the anterior end of the calcarine fissure and running horizontally backwards along that fissure to the tip of the occipital lobe. This lesion had destroyed all the cortical and subjacent white substance between the collateral and calcarine fissures, and it had spread upwards, involving the lower and hinder part of the cuneus.

Cerebellum.—On the under surface of the right hemisphere of the cerebellum was another extensive area of old-standing softening, measuring 4 cm. in the antero-posterior by 5 cm. in the lateral direction; internally this area reached to within about 1·5 cm. of the middle line; posteriorly and externally it almost touched the margin of the hemisphere, and anteriorly it approached to within a couple of cm. of the margin. It represented a destruction, to a depth of from 1·5 to 2 cm., of the outer third or half of the inferior anterior lobe, of the major part of the inferior middle and inferior posterior lobes, and of that part of the superior posterior lobe which is seen on the ventral and posterior aspect of the hemisphere. The area destroyed corresponded to the distribution of the right posterior inferior cerebellar artery. The nucleus dentatus was intact.

Microscopic Examination.

A microscopic examination was made of:—(*a*) a series of posterior root ganglia; (*b*) a series of spinal nerve-roots; (*c*) a series of peripheral nerves; (*d*) the spinal cord.

(*a*) *Posterior Root Ganglia.*

Of the posterior root ganglia the following were examined—the 5th, 8th, 9th, 10th, 11th and 12th dorsal, and the 1st and 2nd lumbar of the right side and the 8th, 9th, 10th, 11th and 12th dorsal, and the 1st and 2nd lumbar of the left side.

The method of examination employed in the case of each of these ganglia, with the exception of the 10th and 11th dorsal of the right side, was as follows:—The entire ganglion, along with the attached spinal nerve-roots, and a portion of the conjoint peripheral nerve-trunk, was stained *en bloc* by the method of Marchi, with the object of demonstrating whether any acute degeneration of medullated nerve-fibres existed. After embedding in celloidin, serial sections were cut in the longitudinal direction, and every section of the series was mounted. In the case of the 10th and 11th dorsal ganglia of the right side the block was divided into two equal halves; one portion was then cut longitudinally, the other transversely.

Dorsal 12. *Right.*—This ganglion shows profound changes (plate 8, figs. 1 and 2). Situated immediately beneath the capsule, mainly in the distal half of the ganglion, is a definite circumscribed focus of disease which extends inwards for a distance of 1·25 mm., and involves, roughly speaking, from one-fourth to one-third of the ganglion. This area has a deep brown uniformly granular aspect, and contains neither nerve-cells nor nerve-fibres; its outline is wavy, and its shape necessarily varies in different sections. It is obviously the broken-down remains of a large hæmorrhage, around which secondary sclerotic changes have occurred.

The sheath of the ganglion overlying this focus is markedly thickened by what appears to be a small round-cell proliferation, and the blood-vessels ramifying therein are extremely congested and stand out prominently. A zone of ganglionic substance lying in contact with and bounding the diseased focus, is also disorganised; it stains palely, and in it there is an apparent proliferation of fibro-cellular connective tissue elements. The blood-vessels within this zone are congested, and nerve-fibres and nerve-cells have disappeared.

In other parts the sheath of the ganglion looks healthy, and the remainder of the ganglionic substance contains nerve-cells and nerve-fibres in normal abundance. The method of Marchi, of course, does not permit of any judgment concerning the existence of fine changes in these nerve-cells. But in the strands of nerve-fibres intertwining the ganglion cells, marked indications of degeneration can be demonstrated. For in the first place, compared with sections of normal ganglia, the fibres are in parts scanty, and it looks as if a considerable number had entirely vanished as a result of past degeneration; and, secondly, along the course of many of those which remain, globules and lumps of blackened fat, typifying acute parenchymatous degeneration, may be seen.

Dorsal. Left.—This ganglion is normal and shows none of the changes seen in the ganglion of the opposite side.

Dorsal 5, 8, 9, 10 *and* 11. *Right and left.*—Show no change.

Lumbar 1 *and* 2. *Right and left.*—Show no change.

(*b*) *Spinal Nerve-roots, Anterior and Posterior.*

Dorsal 12. *Right.*—The bundles forming the posterior nerve-root show two important changes. Firstly, in a number of fasciculi there is a pronounced disappearance of healthy nerve tubules and a substitution of fibro-cellular connective tissue elements. In some bundles hardly a single medullated nerve-fibre can be discerned. Secondly, many of the fibres which remain are undergoing acute degeneration, and others show partially absorbed degenerative products along their course. The anterior root contains its full complement of nerve-fibres and shows no change resembling that seen in the posterior root.

Dorsal 12. *Left.*—Both posterior and anterior roots show no change.

Dorsal 8, 9, 10 *and* 11. *Right and left.*—Show no change.

Lumbar 1 *and* 2. *Right and left.*—Show no change.

(*c*) *Conjoint Nerve-trunks Peripheral to Ganglia.*

Dorsal 12. *Right.*—Close up to the ganglion, where the motor and sensory fibres are enclosed in separate bundles, the latter show marked changes. The sensory group is almost entirely composed of fibro-cellular tissue, in which run congested blood-vessels, and contains hardly any nerve-fibres; those nerve-

fibres which remain in this bundle nearly all contain degenerate products.

On the other hand, the motor bundles are filled with their full complement of healthy nerve-fibres.

These points can be excellently seen in both the transverse and longitudinal sections of the nerve-trunks.

In the nerve-trunk, about two inches away from the ganglion, though little or no acute degeneration can be discovered, there is still an undoubted diminution in number of healthy nerve-fibres; two fasciculi contain hardly any nerve-fibres at all, and absolutely none of the others possess their full complement.

Dorsal 12. *Left.*—On this side the peripheral nerve differs markedly from that on the right side, for here all the bundles are well filled with normal fibres.

Dorsal 5, 8, 9, 10 *and* 11. *Right and left.*—Show no change.

Lumbar 1 *and* 2. *Right and left.*—Show no change.

(*d*) *Spinal Cord.*

Method of examination.—Portions of the cord were taken from the levels of entry of all nerve-roots from the 3rd sacral to the 1st cervical inclusive; these blocks were stained by the method of Marchi and cut transversely; several longitudinal sections of portions of the 10th, 11th and 12th dorsal blocks were also made (plate 12, fig. 2).

Dorsal 12.—It has been already noticed that in that portion of the 12th dorsal posterior root of the right side situated between the ganglion and the spinal cord, the morbid change consisted of sclerosis and acute degeneration combined, the former predominating. Now on entering the spinal cord it is to be observed, firstly, that exactly at the point where the pencils of the root penetrate the cord there is a brief length where there is no degeneration at all (as Obersteiner has shown the fibres here are bereft of their medullary envelope); secondly, that as soon as the pencils of the root enter the cord acute parenchymatous degeneration immediately becomes evident and sclerosis is absent or unrecognisable. In transverse sections the degenerated fibres are well seen in the first part of their course cut longitudinally and running for a short distance alongside the inner margin of the tip of the posterior cornu. In longitudinal sections made parallel to the right posterior cornu, the same fibres are beautifully displayed obliquely cut immediately after they enter. In the postero-external columns of the same side transverse sections show some 70 to 100 degenerated fibres immediately opposite the substantia gelatinosa Rolandi. These fibres are derived from pencils of the root which, entering lower down, have at this level assumed a vertical direction. Furthermore, situated in the centre of the right posterior horn, almost midway between the column of Clarke and the caput cornu, is a small isolated bundle of degenerated fibres of delicate calibre; these also seem to have come

from the posterior root at a lower level. All these degenerated fibres, both those in the postero-external column and those within the posterior cornu, are well seen in longitudinal section. In the next place, a few fibres of the right anterior root exhibit signs of degeneration in their intraspinal course.

Lastly, scattered all over the field of the right lateral pyramidal tract are degenerated fibres of large calibre, and a few diseased fibres are visible in the left anterior and the left lateral pyramidal tracts. This degeneration is a typical descending one, the result of the lesion in the left cerebral hemisphere described in the autopsy report; it can, of course, be seen in all the succeeding sections, but as it obviously has no association with the herpetic lesion it will not be further alluded to.

Dorsal 11.—In transverse sections the entering fibres of the right posterior root are very different from those of the level last described, little if any degeneration being present in them. The degenerated fibres in the postero-external column are most numerous opposite the substantia gelatinosa Rolandi, but the field in which diseased fibres may be found extends further inwards towards the posterior commissure than it did at dorsal 12. The isolated degenerated bundle in the right posterior cornu is still visible. The anterior roots are healthy.

Longitudinal sections confirm these appearances.

Dorsal 10.—In transverse sections the field in the right postero-external column containing degenerated fibres has considerably altered its position. The outer half is separated by a distinct interval from the posterior cornu, and internally the strip reaches to a point almost opposite Clarke's column, and in this central part the diseased fibres are more densely packed than in the outer portion.

The degeneration in the isolated bundle in the posterior cornu is disappearing, and the entering posterior root fibres look healthy.

Dorsal 9.—The degenerated fibres have shifted their position still further inwards towards the middle line, and are now mainly situated in the inner half of the postero-external column. The strip begins in the neighbourhood of Clarke's column and extends to the periphery, and fibres in the centrally situated part of the strip are again more closely aggregated than those in the peripheral part. The degeneration in the isolated bundle in the posterior cornu has disappeared. The anterior roots are normal.

Dorsal 8.—The fibres in the outer portion of the degenerated strip in the right postero-external column are becoming sparse and scattered.

Dorsal 7.—At this level a small number of fibres at the centre of the strip lie in the outer part of the postero-internal column. At either extremity the strip curves towards the posterior horn.

Dorsal 6.—The degenerated fibres are pushed still further inwards and compared with the sections from Dorsal 11; there is

an obvious diminution in their numerical strength. In all about 150 diseased fibres can be counted against about 210 at the lower level.

Dorsal 5.—With the exception of its most peripheral and central parts, the strip is now confined to the postero-internal column.

Dorsal 4.—There is a further diminution in the number of the degenerated fibres. Those situated in the inner half of the strip are again more densely packed.

Dorsal 3.—The strip of degeneration shows signs of being divided into two portions; scarcely any degenerated fibres are visible at its middle, at the periphery a few disseminated fibres are still visible in the postero-external column, and centrally there is a thin strip of diseased fibres reaching almost to the posterior commissure.

Dorsal 2.—At the periphery of Burdach's column there are a few scattered degenerated fibres, and in the inner two-fifths of Goll's column others arranged in a row bordering on the posterior median septum.

Dorsal 1.—Similar to dorsal 2.

Cervical 8.—The number of degenerated fibres has greatly diminished.

Cervical 7.—A minute number of scattered degenerated fibres can be made out in the inner one-third of the postero-internal column, and also at the periphery of Burdach's column. Above this level the degeneration cannot be definitely traced.

Lumbar 1.—The entering posterior roots are healthy, and the posterior columns contain no degenerated fibres. The only degeneration discoverable is in the pyramidal tracts, and this has already been referred to.

Lumbar 2, 3, 4 and 5 show no degeneration referable to the herpes.

Sacral 1, 2 and 3 show no degeneration referable to the herpes.

Case 9.—Richard K., aged 36. Admitted to Claybury Asylum, April 19, 1898. Died February 5, 1899.

SUMMARY.

A typical case of dementia paralytica, developed an attack of herpes zoster over the area in fig. 9. *He died of exhaustion* 153 *days afterwards.*

Microscopically.—The 7th dorsal posterior root ganglion of the right side showed extremely marked sclerotic changes, with destruction of ganglion cells and fibres over that part opposite to the position of the anterior root. No other ganglion was affected.

The corresponding posterior root showed not only some slight

change by Marchi's method, but also evident diminution of fibres by the Marchi-Pal method.

The spinal cord showed acutely degenerated fibres (Marchi's method), entering at the level of the 7th dorsal root on the right side and passing up in the posterior columns to the level of the 2nd dorsal root.

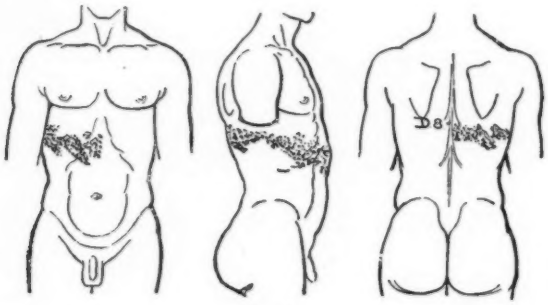

FIG. 9.

To show the distribution of the eruption in Case 9.

On admission he was grossly demented, dull, apathetic and slow of speech. His memory was markedly affected; he knew his name and age, but nothing else. He had no idea of the date, where he was, or how long he had been in the asylum.

His pupils were regular and reacted to light and accommodation. His knee-jerks were not obtained. His gait was slow and tremulous.

On September 6, 1898, he developed a profuse eruption of herpes zoster over the area of the 7th dorsal. The whole area was beautifully marked out as in fig. 9.

By October, 1898, he had become destructive, wet and dirty. His speech was very slow and slurred. His pupils did not react to light. He was much emaciated.

On February 5, 1899, he died of exhaustion, 153 days after the eruption.

POST-MORTEM EXAMINATION.

Twenty hours after death. The body had been kept in the cold chamber from shortly after death until the examination was made.

The body was much emaciated and three deep scars remained to show where the eruption had been situated. The two posterior ones were slightly ulcerated, and looked as if healing had once occurred and the thin deep scar had slightly broken down again.

Brain.—The pia-arachnoid was everywhere adherent.

The convolutions were wasted and the lateral ventricles dilated and granular. The right hemisphere weighed 603 grammes, the left 603 grammes.

The 4th ventricle was granular, cerebellum normal.

Thorax.—The right pleura was adherent at the apex. The apex of the right lung showed several large, active, tubercular foci, but elsewhere the right lung showed broncho-pneumonia with hypostatic congestion of the lower lobe.

The left pleura was adherent at its posterior border. The upper lobe of the right lung was infiltrated with active tubercle, and there was a cavity at the apex of the size of a walnut. The lower lobe was much congested.

Heart normal, aorta slightly atheromatous.

Abdomen.—Liver, spleen and kidneys normal.

Microscopical Examination.

The following parts were examined: (*a*) a series of posterior root ganglia; (*b*) a series of posterior roots; (*c*) the spinal cord.

(*a*) *Posterior Root Ganglia.*

The ganglia examined were the 6th, 7th, 8th and 9th dorsal on both sides. They were hardened in Müller's fluid. A transverse cut was then made through each with a sharp razor, and each ganglion was placed in Marchi's fluid. Each ganglion was embedded in celloidin and cut longitudinally in series. The sections were counterstained by van Gieson's method, by safranin, or by Pal's method.

Dorsal 7. Right.—This ganglion shows a remarkable change. Even in the specimens stained by Marchi's method only this change is pronounced, but it is best seen when the sections are counterstained with van Gieson's stain (plate 1, fig. 2B). On that side of the ganglion opposite to the anterior root about one-third of the ganglion obliquely is converted into dense fibrous tissue, in which not a nerve-fibre or nerve-cell can be seen. This focus stains a brilliant red in contradistinction to the somewhat purple interstitial tissue of the normal ganglia, and this is evident even to the naked eye. Thus if sections of the right and left 7th dorsal ganglia counterstained by van Gieson's method are mounted side by side, there is no difficulty in picking out the right ganglion with the unaided eye in consequence of its brilliant red colour. The ganglion of the left side, owing to the presence of the bundles of healthy nerve-fibres and healthy cells, and the absence of dense connective tissue, appears of a purple red colour.

The posterior root and peripheral nerve attached in the longitudinal sections of the right ganglion are converted into fibrous tissue, which also stain brilliant red by van Gieson's method.

Dorsal 7. *Left.*—This ganglion is absolutely normal (plate 1, fig. 2A).

Dorsal, 6, 8 *and* 9. *Right and Left.*—Absolutely normal.

(*b*) *Posterior Nerve-roots.*

Dorsal 7. *Right.*—This root shows no profound degeneration by Marchi's method, but in many places the sheath of the fibres is broken up and swollen, and here and there a few blackly-stained swollen remains of degenerated fibres can be seen. But when stained by the Marchi-Pal method the difference between this root and its companion root on the other side is evident, for the right root shows a marked decrease of fibres. No large deposition of secondary connective tissue is shown by any of the various counterstains employed.

Dorsal 7. *Left.*—This root is absolutely normal.

Dorsal 8. *Right.*—On comparing this root with that of the opposite side there are perhaps fewer fibres. No definite change by Marchi's method.

Dorsal 8. *Left.*—Normal.

Dorsal 9. *Right and Left.*—Normal.

(*c*) *Spinal Cord.*

The cord was hardened in Müller's fluid and stained by the Marchi method. Every segment was then cut and some sections from each segment were stained by Schäfer's modification of the Pal method (plate 11, fig. 3).

Beginning from below upwards, the upper lumbar and lower dorsal segments presented the following appearance:—There was acute degeneration on both sides (Marchi) and a slight amount of sclerosis (Marchi-Pal) in the pyramidal tracts. The posterior column and root zones were entirely free from acute degeneration and sclerosis.

However, at the level of the 8th dorsal root a few black dots are visible in the right posterior horn, which appear to be definite degenerated fibres.

At the level of entry of the 7th dorsal root a mass of degenerated fibres is seen streaming into the cord with the posterior root (plate 14., fig. 1.). One segment higher these fibres are extremely marked, but are now situated entirely in the root zone on the inner side of the posterior horn, and the posterior horn is free from degenerated fibres.

At the level of the 5th dorsal root they are still well seen, but they tend to be separated from the posterior horn by normal fibres. At the level of the 4th dorsal root they diminish in number and become more scattered. At the level of dorsal 3 they are still more diffuse and situated more at the periphery, and at the level of dorsal 1 it is doubtful if any degeneration can be seen.

Throughout the whole of these sections and upwards into the medulla the same degeneration in the pyramidal tracts present below the entry of the affected 7th dorsal root can be seen.

Case 10. — William J., aged 40, admitted to the County Asylum, Rainhill, October 6, 1898. Died July 29, 1899.

SUMMARY.

Suffered from dementia paralytica in a typical form. On October 30, 1898, *an herpetic eruption appeared over the 4th cervical area of the right side* (*fig.* 10). *Death from general paralysis and phthisis on July* 29, 1899, 272 *days after the attack of herpes.*

Microscopic examination reveals an extensive area of sclerosis in the 4th cervical posterior root ganglion of the right side, evidently the remains of a previous destructive process. In the corresponding posterior root and also in the peripheral nerve there was likewise evidence of sclerosis but no acute degeneration.

The spinal cord showed no acute degeneration.

The spinal cord also shows some tabetic sclerosis, but this does not invalidate the case, as it is due to an affection of lumbo-sacral roots.

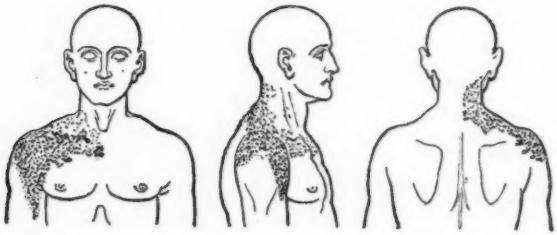

FIG. 10.

To show the distribution of the eruption in Case 10.

History.—Four months before admission he became strange in his manner. He became restless, and would pick up valueless articles, bringing them home and stating they were of much importance. He became extremely erotic, but his wife denied that he had been infected with syphilis. She has never been pregnant. Just before admission to the asylum he had a seizure and the mental symptoms grew worse.

On admission.—He was of slim build and poor bodily condition. His speech was thick with an occasional catch, and face

and tongue were tremulous. Pupils small, reacted badly to light. No paralysis.

Mentally he was restless, talkative and excited. He failed to recognise that he was in an asylum and was under the impression that he came there to buy geese that were for sale. He was obviously suffering from dementia paralytica.

Progress.—October 29. He had a typical general paralytic seizure.

October 30. He developed an herpetic eruption over the skin area shown in fig. 10. The vesicles were mainly of small size and were densely distributed over the affected region. Anteriorly the eruption was seen to extend onto the lower part of the area usually occupied by the 3rd cervical, but here the vesicles were sparsely scattered. Excepting at its extreme anterior border the eruption was confined to the 4th cervical area as given by one of us, its posterior or lower border corresponding peculiarly accurately. There was pronounced erythema along with the vesiculation. The temperature was 101° F. (38·3° C).

November 3. The erythema had almost disappeared; many of the vesicles contained pus and scabbing had begun.

December 16. Pustulation had ceased. There was not much scabbing.

April, 1899. He had become extremely demented and physically weak. Seizures occurred occasionally.

July 29, 1899. He died from general exhaustion 272 days after the attack of herpes.

Post-mortem Examination.

The *post-mortem* examination was made fifteen hours after death.

External examination.—Height 71 inches, circumference at shoulders 35 inches, circumference of head 21⅝ inches. Muscular and osseous development below the average. No local muscular atrophy, but poorly nourished generally.

On the sternum immediately internal to the junction of the 2nd costal cartilage was a pale brown patch of post-herpetic scarring, about 1·5 cm. in diameter. Over the shoulder just in front of the acromion process of the clavicle were three other small patches; a further patch was seen in front of the shoulder joint and another above and external to the joint; lastly, there were two more small patches situated immediately above and below the outer one-third of the spine of the scapula respectively.

The hair was thin but present all over the scalp.

Cranium and Brain.—The calvaria was slightly thickened, and was denser than usual. The lines of the meningeal arteries were rather deep. Greatest transverse diameter of cranium 14·4 cm., greatest antero-posterior diameter of cranium 18·3 cm., cephalic index 78·6 cm.

The dura mater was relaxed frontally and a very thin, brown,

non-laminated hæmorrhagic membrane lined the concavity on both sides and extended along the falx and into the frontal, temporal and occipital fossæ. The dura was nowhere abnormally thickened, nor unduly adherent to pia-arachnoid or bone.

The subdural fluid was markedly excessive in quantity and tinged brown in colour. For a general paralytic the large vessels at the base looked remarkably healthy.

There was a moderate degree of opacity of the arachnoid over the convexity of the hemispheres, especially over the frontal lobes.

The pia-arachnoid was moderately thickened, somewhat hyperæmic, and on stripping decortication occurred in patches over the frontal and motor regions.

The cerebral hemispheres were of average size, their form was good and there was no asymmetry. The convolutions were simply disposed and a moderate degree of wasting was noticeable, chiefly in the frontal region. The sulci generally were shallow.

On the under surface of the right temporal lobe close up to the anterior extremity were three minute patches of surface softening; these had brown edges and involved the cortex only. Symmetrically placed on the anterior faces of both first frontal convolutions were two similar, but rather more extensive, patches of softening; these also did not extend below the cortex, and in the subarachnoid space above them brown fluid was collected.

The cerebral cortex was darker than normal, somewhat hyperæmic, distinctly thin, and its striation was indefinite.

The white substance had a normal appearance, but was unduly firm. Enlargement of the lateral ventricles was noticeable, but their ependyma was smooth.

The basal nuclei and other structures presented no naked-eye change. The cerebellar cortex was rather dark and thin, but otherwise there was no noteworthy alteration in this organ, nor in the pons, medulla and remaining intracranial structures.

The encephalon weighed 1,324 grammes, the right cerebral hemisphere unstripped 525 grammes, the left hemisphere 530 grammes, and the cerebellum along with the pons and medulla 162 grammes.

Spinal Cord.—The spinal cord seemed to be somewhat small, and there was an obvious excess of cerebro-spinal fluid, but otherwise there was no naked-eye alteration to note, nor could anything pathological be detected at this stage in the posterior root ganglia and spinal nerves extracted.

Thorax.—Chest narrow. Ribs easily broken. There were old firmly-united fractures of the following ribs on the left side:—the 6th at the costo-chondral articulation, the 7th 1 inch, the 9th $1\frac{1}{2}$ inches, and the 10th and 11th 2 inches external to the costo-chondral joint respectively. On the right side the 11th rib was broken at about its middle. Round all these fractures a considerable amount of callus had been thrown out, and they were supposed to have been fractured prior to admission to Rainhill.

The right pleura was free from adhesions, but on the left side

there were adhesions round the apex and along the front of the lung. At the apex of the right lung were a few small patches of caseous consolidation. The organ weighed 15 ozs. (424 grammes). The left lung weighed 42 ozs. (1,188 grammes), it was of increased size and severely diseased. The pleura was thickened and fibrous all over. Along the free margin at the base were several large emphysematous bullæ. On section many large tubercular cavities were found in the upper lobe, and all over the lung were scattered patches of advanced caseous consolidation.

The mucous membrane of the larger bronchi was red and thick, and the bronchial glands were enlarged, while some present caseous foci.

The pericardium was normal.

The heart weighed 6¼ ozs. (184 grammes), it was small but of normal shape, its muscle was very firm and of dark colour. Decolourised clot was present in the right auricle, and black clot in the left auricle. There was no valvular disease, but some commencing atheroma, indicated by change of colour and puckering, was noticeable in the thoracic aorta.

Abdomen.—The peritoneum was normal.

The liver weighed 43 ozs., its capsule was thick and white in patches on the convexity, its substance dark and firm.

Gall bladder normal.

Spleen weighed 3 ozs. (85 grammes) and was healthy.

Each kidney weighed 4 ozs. (113 grammes). The capsule peeled cleanly, but the substance was very dark and firm.

The adrenals, pancreas and stomach were healthy.

Along a short length of the small intestine just above the cæcal valve and on and immediately below the valve were about eight small tubercular ulcers, some of which were in quite an early stage of development.

The lymphatic glands of the mesentery were slightly enlarged. The bladder was partially distended with dark urine.

On the dorsum penis immediately behind the corona was a suspicious but indefinite scar (possibly syphilitic).

The left testicle showed a few abnormal streaks on section, which suggested previous orchitis.

The prostate gland and seminal vesicles were normal.

Microscopic Examination.

A microscopic examination was made of (*a*) a series of posterior root ganglia, (*b*) a series of spinal nerve-roots, (*c*) the spinal cord.

(*a*) *Posterior Root Ganglia.*

Of the posterior root ganglia the following were submitted to examination:—the 2nd, 3rd, 4th, 5th, 6th and 7th cervical of both sides.

Method of examination.—To prevent error and confusion the individual ganglia, along with that portion of the roots lying central to the body of the ganglion but outside the dura, together with about 5 mm. of the peripheral conjoint nerve-trunk, were taken separately and hardened in different bottles; first in formol 5 per cent. for a week or more, then in alcohol, &c., preparatory to celloidin imbedding. Corresponding pairs from the two sides were then fixed in celloidin side by side on the one block, that from the right side always being distinguished by having a piece of heart-muscle or other distinctive tissue placed alongside it. Serial transverse sections were next cut from one end to the other. To stain these the hæmatoxylin method of van Gieson was employed, and in mounting the finished preparations care was taken to preserve them in strict serial order.

Cervical 4. Right.—As this is the only ganglion to show important changes we shall describe it first. There are 175 sections (plate 6, fig. 1B).

Beginning at the central end where the roots pierce the dura, it soon becomes evident that the ventralmost bundle of the posterior root is diseased. It is composed of fibrocellular material instead of nerve-fibres, and the sheath immediately external to it also contains a deposit of small round cells. This diseased bundle can be traced right through all the sections of the roots up to the ganglion, where it runs into a diseased focus which will be presently described. The remaining bundles of the right posterior root, along with the anterior roots of both sides and the posterior root of the left side, are free from noteworthy alteration.

Just before the ganglion begins marked thickening of the sheath of the right posterior root on its ventral side becomes apparent, and is continued through a dozen or more sections.

In section 93 (soon after the beginning of the ganglionic tissue) an obvious focal lesion comes into view. It gradually increases in size and then fades away, and is evident in about forty sections altogether. Where it is well-developed it appears in transverse sections as a large patch on the ventral side of the ganglion, which extends from the surface inwards and involves about one-third of the body. The internal line of demarcation is fairly sharp. The whole of this area is composed principally of wavy fibrous tissue with elongated nuclei, just a few nerve-fibres can be discerned in it, and with the exception of two or three ganglion cells it is completely denuded of these bodies. The sheath overlying this region is not markedly thickened, and the rest of the ganglion has a normal appearance.

The above-mentioned focus of disease extends almost to the distal end of the ganglion, but when the anterior root begins to fuse with the posterior to form the conjoint peripheral nerve trunk, the area of sclerosis soon diminishes in extent. The sclerosis, however, does not cease here, for it is quite clear that the change is continued into the nerve-trunk and that a considerable number of nerve-fibres have been replaced by fibro-cellular tissue.

It is obvious from the general appearances that this ganglionic lesion is of considerable standing, and has long passed the acute stage.

One or two small arteries are to be observed in the sheath of the ganglion which have an appearance suggestive of syphilitic endarteritis, but there is no definite histological evidence which will explain the origin of the lesion.

Cervical 4. *Left.*—This ganglion shows no noteworthy change.

Cervical 2. *Right and Left.*—There are one or two syphilitic-looking arteries in the conjoint trunks, but apart from this the ganglia of both sides and their annexa present no change worthy of notice.

Cervical 3, 5 *and* 6. *Right and Left.*—These ganglia are practically normal.

Cervical 7. *Right and Left.*—Almost one-third of the anterior root of the right side appears to be sclerosed. The change is represented by a collection of small round cells and fibrous tissue, and it runs through all the sections.

In the tissues investing the posterior roots of both sides there is an apparent excess of small round cells. This is in all likelihood an early tabetic change.

The Posterior Spinal Nerve-roots.

After preliminary fixation in Müller's fluid the spinal cord in the cervical region was divided up into its eight segments, and to each segment the intradural portion of the roots was left attached. Then after these blocks, with the roots, had been stained by the method of Marchi, certain of the posterior roots, viz., the 3rd, 4th and 5th cervical of both sides, were cut off close up to the cord, care being taken to preserve the bundles in normal relative position. The bundles were then divided into two portions, the peripheral portions were teased, and the central portions embedded in celloidin and cut serially in the longitudinal direction.

Cervical 4.—The posterior root of the right side is practically composed of four main bundles, of which the upper three show no change of importance. A single acutely degenerated fibre is visible here and there, but there is no collection of degenerated fibres, and no evidence of sclerosis.

In the fourth and lowermost bundle there is, however, a morbid alteration, namely, a pronounced disappearance of nerve-fibres and a substitution for them of fibrous tissue. Roughly speaking about half the fibres of this bundle are absent, and the change is as noticeable in the teased preparations as in the serial longitudinal sections. This probably represents the remains of past degeneration.

The 4th cervical posterior root of the left side is also composed of four main bundles, but in none of them is there any noteworthy acute degeneration or sclerosis.

Cervical 3 *and* 5.—The posterior roots of these segments were put to the same searching examination as those of cervical 4, but no change calling for special notice was discovered.

Spinal Cord.

Method of Marchi. Transverse sections.

Cervical 2.—In the centre of the posterior columns there is a wedge-shaped strip of partial tabetic sclerosis. Through the centre of this runs the postero-median fissure, and it practically embraces the whole of the columns of Goll. Its position clearly shows that it originates from disease of roots placed below the cervical region.

In both postero-external columns there are a few scattered degenerated fibres, but there is no degeneration which can be referred to the herpes. The entering posterior root-fibres are free from acute disease.

Numerous acutely degenerated fibres are seen in the direct and lateral pyramidal tracts of both sides, but such degeneration is almost invariably seen in cases of dementia paralytica, and can be attributed to that disease.

Cervical 3.—Shows exactly the same changes as cervical 2.

Cervical 4, 5 *and* 6.—All show similar changes, and nowhere can any change be found corresponding in any way to the herpetic lesion.

Case 11.—Rachel R., aged 64, admitted to Claybury Asylum, January, 1897. Died October 6, 1898.

SUMMARY.

On June 12, 1897, *a typical case of so-called senile melancholia developed an attack of herpes zoster over the* 4*th dorsal area of the right side* (*fig.* 11). *The eruption was extremely profuse, and the whole area was excellently marked out.*

She died on October 6, 1898, 481 *days after the attack of zoster.*

Post mortem.—The axilla showed slight but definite scarring. There were no signs of any disease of the nervous system except such as were due to the zoster.

On microscopical examination the 4*th dorsal posterior root ganglion of the right side showed thickening of the capsule and replacement of a considerable area of ganglionic substance by fibrous tissue. This change occupied that portion of the ganglion opposed to the anterior root.*

The 3*rd and* 4*th dorsal segments of the spinal cord were examined by Nissl's method, and showed no change. The remainder of the cord was normal.*

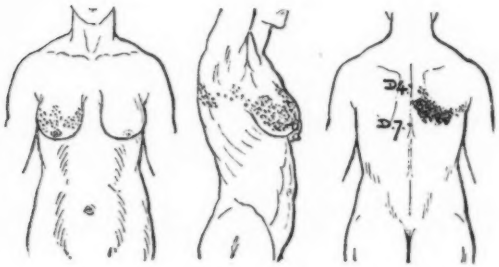

FIG. 11.

To show the distribution of the eruption in Case 11.

On admission she was depressed and inclined to be violent. Memory good. The pupils reacted normally, and knee-jerks were normal. She had no signs of any general nervous disease.

June 12, 1897. She developed an attack of herpes zoster over the 4th dorsal area of the right side (fig. 11), during which she was seen by one of us. Her temperature was 100°. Arteries much thickened. Some emphysema. She was a typical case of so-called senile melancholia.

She died on October 6, 1898, of acute colitis, 481 days after the attack of zoster.

POST-MORTEM EXAMINATION.

Nineteen hours after death. *Post-mortem* rigidity was passing off.

There were no external scars except a few white marks in the right axilla, which may have been produced by the attack of herpes zoster.

There was general œdema and marked congestion of the right lung. The whole upper lobe and upper part of the lower lobe of the left lung were solid with patchy pneumonia. There was much surrounding congestion and œdema.

Heart showed no valvular disease. The muscular substance was fair considering the patient's age. Kidneys and spleen normal. Liver was congested, and showed some fatty change.

Examination of the Nervous System.

The membranes were slightly thickened and opaque over the upper part of the ascending frontal, parietal and paracental convolutions. There was also some thickening over the cerebellum in the middle line both above and below. Excess of fluid in the meshes of the pia-arachnoid, but the brain could be stripped with-

out difficulty, or the occurrence of decortication. The substance of the brain was normal.

The arteries at the base of the brain showed marked atheromatous changes.

The spinal cord and ganglia showed no naked-eye abnormality.

Microscopical Examination.

The following parts were examined microscopically:—(*a*) a series of posterior root ganglia; (*b*) a series of peripheral nerves close to their entry into the ganglion; (*c*) the spinal cord.

(*a*) *Posterior Root Ganglia.*

The 1st, 2nd, 3rd, 4th, 5th and 6th dorsal ganglia of both sides were hardened in Müller's fluid, embedded in celloidin, and cut longitudinally. The sections were cut in series, and the sections as cut were laid on a glass plate covered with a thin film of collodion. Then a thin film of collodion was poured over the whole, and the double collodion film, between the two layers of which lay the sections in strict series, was detached from the glass plate by laying the whole in alcohol. By this method a series of films was obtained which could be treated by various staining methods, and yet the sections remained in strict series. The staining methods used were the Weigert, Weigert-Pal, hæmatoxylin, hæmatoxylin and eosin, and van Gieson's method.

Dorsal 4. *Right.*—The first sixteen longitudinal sections pass mainly through the capsule and pericapsular tissue. In this tissue a vessel is seen which has undergone marked atheromatous changes. Internal to the muscular coat the wall of the vessel is much thickened, the lumen is irregular and almost blocked. The internal and middle coats are so fused that it is impossible to say how much of this thickening is due to the middle, and how much to the internal layer.

From the seventeenth to the thirty-first section, all of which pass through the substance of the ganglion, the following definite changes are seen. The ganglionic substance is perfect except on that side opposite to the anterior root. Here the substance of the ganglion is adherent to the capsule by firm fibrous tissue. The capsule itself is altered in structure by the substitution of firm connective tissue for the loose wavy layers of which it is usually composed. This condition of scar-formation gradually increases until at last nearly one-third of the substance of the ganglion contains neither cells nor fibres, but is occupied by dense fibrous tissue. The condition closely resembles that found in Case 9, and figured on plate 2, fig. 3.

From the thirty-first to the sixty-sixth section no very definite change can be seen, but with the sixty-sixth section we again find that the sheath is thickened. But here it dips down into the

ganglionic substance as a deep pucker, and around this pucker cells and fibres are almost completely absent. This condition extends over about twelve sections and then disappears.

Both these scars lie on that side of the posterior root ganglion opposite to the anterior root, but the first mentioned lies nearer the exit of the posterior roots, the latter nearer the entry of the peripheral nerve. They are probably the remains of a considerable acute lesion probably closely resembling in the acute condition that figured on plate 2, fig. 1.

Dorsal 4. *Left.*—This ganglion is perfectly normal.

Dorsal 1, 2, 3, 5 *and* 6. *Right and left.*—Show no change.

Posterior roots.—Owing to the mistaken method adopted with the spinal cord, no posterior roots could be examined in that region, where they might have been expected to have undergone change.

(*b*) *Peripheral Nerves.*

All the peripheral nerves were normal excepting the nerve that enters the 4th dorsal ganglion of the right side. This nerve seems to have lost fibres, but as these nerves were not cut transversely, the number of fibres lost cannot be counted.

(*c*) *Spinal Cord.*

At the time this case died we were anxious to see if the cells of the spinal cord underwent any change in consequence of the herpetic lesion. The 3rd and 4th dorsal segments were therefore removed at the *post mortem* and placed in 96 per cent. alcohol. They were stained by Nissl's method and various modifications of this method, but showed no abnormality.

The remainder of the cord was hardened in Müller's fluid, and showed neither acute degenerative nor sclerotic changes.

Case 12.—Alice Mary S., aged 20. Admitted to Rainhill Asylum, September 2, 1891. Died July 15, 1898.

Summary.

A female, aged 20, *suffering from congenital idiocy, developed a severe and extensive herpetic eruption over the* 12*th dorsal area of the left side, on February* 15, 1897 (*fig.* 12).

Death from phthisis on July 15, 1898, *one year and* 150 *days after the appearance of the eruption.*

On microscopic examination the following changes were found:—

(*a*) *Posterior root ganglia.—The* 12*th dorsal ganglion of the left side showed a focal lesion. A localised portion of the sheath was markedly thickened and the nerve-cells and nerve-fibres subjacent to this focus were destroyed.*

(*b*) *Posterior spinal nerve-roots.—One small bundle of the 12th dorsal posterior root was partially sclerosed; this bundle could be traced onto the ganglionic lesion just mentioned.*

(*c*) *Peripheral nerves.—No obvious pathological change.*

(*d*) *Spinal cord.—No obvious pathological change.*

FIG. 12.

To show the distribution of the eruption in Case 12.

History of case unobtainable.

State on admission.—Physically ill-nourished and feeble, and possessed of a delicate frame and poor muscles. Skin healthy. Opacities on both corneæ, but the pupils were equal and their margins regular and they reacted to light and accommodation. Tendon reflexes normal. No paralysis. No heart murmurs. Pulse 120. Chest narrow and deep, no flattening, but distinct dull percussion note at right apex. Teeth good. Alimentary and other systems apparently healthy.

Mentally a complete idiot, unable to express herself in any way. Quite regardless of her surroundings. Wet and dirty and requiring constant attention. Saliva poured continuously from her mouth.

Progress of case.—February 15, 1897. Developed an extensive crop of herpetic vesicles with considerable erythema over the region of the left loin and upper part of the buttock, as indicated in the accompanying fig. 12. The vesicles were largest and most numerous over the anterior part of the iliac crest. A few small scattered vesicles were seen on the abdomen in the iliac region, and posteriorly immediately to the left of the 4th and 5th lumbar and 1st sacral vertebræ some large concrete ones were noticed.

February 22, 1897. Most of the vesicles were purulent, some were scabbing, and the erythema had vanished.

July 26, 1897. The eruption had disappeared and left practically no scarring.

July 1, 1898. Signs of phthisis more pronounced.

July 10, 1898. Rapidly losing weight. Marked dulness over both upper lobes of lungs. Temperature hectic.

Died July 15, 1898, one year and 150 days after the date of appearance of the herpetic eruption.

Post-mortem Examination.

The spinal cord and certain posterior spinal root ganglia and peripheral nerves were extracted twelve hours after death; the full autopsy was performed thirteen and a half hours later. Weather warm and dry.

External appearances.—Body greatly emaciated. Legs and arms slightly drawn up. A circular bedsore over the sacrum, one and a half inches in diameter, denuding the bone. Slight scarring, only visible over the left iliac crest, the sole remains of the herpetic eruption.

Head.—Scalp healthy, calvaria of small size, bone of normal thickness and density. Dura mater well stretched, not abnormally adherent to bone or arachnoid, not unduly thickened. A small amount of black blood clot in dural sinuses. Subdural cerebro-spinal fluid present in excess; no blood or membrane.

Brain small, encephalon weighing only 1,154 grammes, but cerebral hemispheres equal and segments proportionately and symmetrically represented. Weight of right cerebral hemisphere, unstripped, 462 grammes; left, 460 grammes. Pia generally anæmic, but of normal density and not adherent. Convolutions of brain arranged on a simple type, the individual gyri small and the sulci rather wide. Cortex pale, firm, anæmic, and reduced in depth. White substance pale and firm; lateral ventricles somewhat dilated and containing an excess of fluid. Basal nuclei normal. Weight of cerebellum 127 grammes, the two hemispheres of equal size, cortex pale and thin, and the white substance pale and firm. Weight of pons and medulla together, 34 grammes; no macroscopic change to note in them, nor in the cranial nerves, nor base of skull.

Spine.—The spinal cord and the posterior root ganglia extracted also showed no naked-eye change.

The vertebræ were healthy.

Thorax.—Some pleural adhesions existed at either apex. Throughout the upper lobes and in the upper parts of the lower lobes of either lung, were scattered patches of consolidation. These patches were to a large extent caseated, and in some small abscess cavities had formed. The right lung weighed 10 ozs. (283 grammes), the left 8 ozs. (226 grammes).

Pericardium healthy. Heart very small, weighing only 3 ozs. (85 grammes), but otherwise normal; auricles contained a small amount of pale blood clot; muscle pale but firm. No organic valvular disease.

Abdomen.—No abnormal adhesions or fluid in peritoneum. Omentum very thin.

The liver weighed 24 ozs. (671 grammes), and though small it looked healthy. Gall bladder normal.

Spleen weighed 2 ozs. (56 grammes), also small, but of good colour and consistence.

Each kidney weighed 2 ozs. (56 grammes); they were small, but the capsule peeled clearly, and the substance was of good colour. Suprarenal capsules healthy.

Pancreas and stomach normal.

In the small intestine a few tubercular ulcers of small size were seen at the lower end of the ileum; the large intestine was healthy.

Bladder distended with thick fœtid urine, mucous membrane swollen and almost black in colour.

Uterus and ovaries healthy.

Microscopical Examination.

A microscopical examination was made of (*a*) a series of posterior root ganglia; (*b*) a series of posterior spinal nerve-roots; (*c*) a series of peripheral nerves; (*d*) the spinal cord.

(*a*) *Posterior Root Ganglia.*

The posterior root ganglia examined were the 9th, 10th, 11th and 12th dorsal and the 1st lumbar of both sides, and the method employed was as follows:—After hardening in Müller's fluid and alcohol in the usual manner, corresponding pairs of ganglia from the right and left sides were taken and embedded in celloidin side by side in one block, special means being employed for distinguishing the right ganglion from the left. Serial transverse sections of the two ganglia were then cut. These were arranged in strict order between two thin layers of celloidin, and stained by the copper-hæmatoxylin method of Weigert. In this manner an examination of and a comparison between corresponding pairs of ganglia was conveniently and effectively carried out.

Dorsal 12. *Left* (*commencing from that end of the ganglion which lies nearest to the spinal cord*).—The first thirty-six sections exhibit no obvious departure from normal. Then follows a point where the ganglionic sheath begins to be markedly thickened, the first indication of a lesion which is continued through all the remaining sections right up to the commencement of the peripheral nerve.

The diseased area as seen on transverse section is situated along the margin of the ganglion on that side of it which is farthest removed from the motor root, to which it lies almost diametrically opposite. The change may be described as follows:—Firstly, the sheath investing from one-fifth to one-

sixth of the circumference in this situation is, roughly speaking, three times thicker than it should be, and it possesses a curious homogeneous non-lamellated aspect in marked contrast with the normal wavy appearance of the remainder of the sheath, and even under a high power of the microscope its structure is indefinite. Secondly, the ganglionic nerve-cells and nerve-fibres lying immediately below this portion of thickened sheath to a depth of about ·500 mm. have totally disappeared and been replaced by adventitious fibro-cellular tissue. The dividing line between this destroyed area and the normal remainder of the ganglionic substance is a sharply-defined one. As the peripheral nerve is approached the destruction of ganglionic nerve-cells and fibres becomes less marked, but the sheath thickening remains, and lying outside it is a collection of material having the appearance of organised blood clot in which numerous small round cells and adventitious blood-vessels are visible.

Dorsal 12. *Right.*—There is no change at all corresponding to that described above.

Dorsal 11. *Left and right.*—There is no difference between the two ganglia, and absolutely no focal lesion exists.

Dorsal 10 *and* 9, *and lumbar* 1. *Left and Right.*—Normal.

(*b*) *Spinal Nerve-roots, Anterior and Posterior.*

Stained by the method of Weigert.

Dorsal 12. *Left.*—In the sensory root there is one small isolated bundle which is partially sclerosed, and does not contain its normal complement of fibres. This sclerosed bundle can be traced along to the diseased focus already described as existing in the 12th dorsal ganglion of the left side. The remainder of the sensory root and the whole motor root seem to be healthy.

Dorsal 12. *Right.*—Normal.

Dorsal 11, 10 *and* 9, *and lumbar* 1. *Right and left.*— Normal.

(*c*) *Conjoint Nerve-trunks Peripheral to Ganglia.*

The 10th, 11th and 12th dorsal and 1st lumbar peripheral nerves of both sides were examined most carefully at distances varying from 1 to 20 cm. from the ganglia by the method of Marchi and by the method of Weigert. The former method displayed no acute degeneration whatever, and the Weigert sections revealed nothing in the left 12th dorsal or any other nerve which could be confidently declared pathological.

(*d*) *Spinal Cord.*

As a portion of the spinal cord taken from the 10th dorsal level, and stained by the method of Marchi showed no morbid change it was considered unnecessary to pursue the examination further.

Case 13.—James E., aged 28, admitted to Rainhill Asylum, January 22, 1890. Died March 17, 1900.

SUMMARY.

A chronic demented patient was attacked by herpes zoster on January 9, 1898. The eruption was distributed in the form of a transversely directed band round the right side of the chest. It began behind opposite the 7th and 8th dorsal spines, and in front lay immediately below the nipple (fig. 13).

Death occurred from tubercular phthisis on March 17, 1900, 790 days after the eruption.

Microscopic examination revealed a distinct lesion in the 6th dorsal posterior root ganglion of the right side. This lesion had undergone transformation into fibrous tissue in which no nerve-fibres or ganglion cells could be seen.

In the corresponding posterior spinal nerve-root, and also in the peripheral nerve, several fasciculi of nerve-fibres were sclerosed.

In the spinal cord no acute degenerative or sclerotic changes could be found that could be in any way referred to the ganglionic lesion.

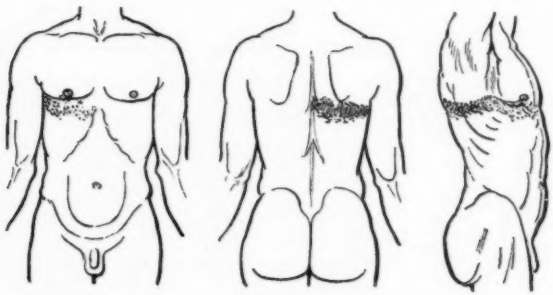

FIG. 13.

To show the distribution of the eruption in Case 13.

Clinical Notes.—Male, aged 28, admitted to Rainhill Asylum on January 22, 1890, on a transfer order from Lancaster Asylum.

No history of the case was obtained.

On admission it was noted that he was of average build, normally nourished and free from physical infirmity.

His mental condition was one of dementia. He was incapable of rendering a coherent account of himself, displayed a marked loss of memory for both recent and remote events, took little interest in his surroundings, was inattentive and unobservant, untidy in his person, and occasionally dirty in his habits.

He remained in this condition throughout his period of confinement, exhibiting no change worthy of record.

On January 9, 1898, he developed a crop of herpetic vesicles, accompanied by much erythema, in the position indicated in fig. 13, made from excellent water-colour drawings, by Mr. Marriott. Viewed from behind the eruption began opposite about the 7th and 8th dorsal spinous processes, and thence extended forwards and slightly downwards in the form of a band fully three inches in width, on a level appreciably below the lower end of the scapula. Gaining the front of the chest this band split up into blotches and streamers; one blotch covered the nipple, but the remainder of the eruption lay below this level. The vesication was soon followed by pustulation, which lasted for a considerable period and left permanent cicatrisation.

On March 10, 1900, it was noticed that he had lost weight during the previous month, but no other alteration in his condition had occurred to attract attention; however, on examination it was discovered that not only was he pyrexic, but also both his lungs were extensively diseased, sharp râles being audible all over them, and cavitation in evidence at the left apex. Diarrhœa was next noticed, and on March 17, 1900, he died, ten years after admission, and 790 days subsequent to the outbreak of the herpetic eruption.

Post-mortem Examination.

The spinal cord and a series of ganglia were extracted twenty-three hours after death, but the full examination was not made until twenty-one hours later, owing to administrative reasons. The weather was cold.

The cadaver was thin but not emaciated, and was below the average in general muscular and osseous development.

No herpetic scarring could be seen on the front or side of the chest, but on the dorsum an inch or more below the angle of the right scapula, and on a level with the spines of the 8th, 9th and 10th dorsal vertebræ, there were several obvious white cicatrices. Otherwise the skin was normal.

Head.—The scalp was healthy and covered by a normal growth of hair. The calvaria was of normal shape, the frontal and occipital bones had an average thickness of 5 and 4 mm. respectively. The lines of the meningeal arteries were plainly marked.

The dura was not unusually adherent to the bone, and was well-stretched. The cerebro-spinal fluid was of normal character, but somewhat excessive in quantity. The dural sinuses were partly filled with black clot. The cerebral veins were engorged with black blood, but the walls of all the larger vessels looked healthy.

The arachnoid was not unduly opaque, and there were no collections of subarachnoid fluid; but the pia-arachnoid mem-

brane, mainly as a result of œdema, was distinctly thickened and soft, and it stripped with great readiness. The pial network of arterioles was injected. The encephalon weighed 1,390 grammes, the right cerebral hemisphere (unstripped) 605 grammes, and the left hemisphere was the same weight as the right. Speaking generally, the brain was of average size, of good shape, and the segments in both hemispheres were proportionately represented. There were indications of slight general atrophy, but no local softening or sclerosis, and the convolutions were somewhat complexly disposed. The cortex in all regions was slightly darker than normal, somewhat hyperæmic, and somewhat reduced in depth, but striation was distinct. With the exception that the puncta cruenta were unduly noticeable, the white matter had a healthy appearance, and was of normal consistence. The ventricles were slightly dilated, but the contained fluid was normal in character, and the ependyma smooth.

The basal nuclei, commissures, &c., showed no naked-eye change. The cerebellum, pons and medulla altogether weighed 182 grammes. In none of these structures, nor in the cranial nerves, was there any alteration worthy of note.

Spine.—During extraction of the spinal cord it was noticed that the vertebræ were abnormally soft, but the cord itself, along with its roots and its membranes, showed no pathological change to the naked eye.

The 3rd, 4th, 5th, 6th, 7th and 8th dorsal posterior root ganglia and several inches of each corresponding peripheral nerve were carefully dissected out, and it was noticed during this process that the nerves on the right side were more adherent to the adjacent pleura than those of the left. (It will be presently noted that the right pleura was extremely adherent all round.)

Thorax.—The intercostal glands on the right side were markedly enlarged. These glands lie quite close, slightly anterior and external, to the posterior root ganglia, and in the normal subject escape notice unless specially searched for. Furthermore, all the fat and connective tissue which invested the ganglia and nerves was darker and more vascular on the right side than on the left, but no special change in any particular ganglion or nerve was discernible.

The right lung weighed 36 ozs. (1,018 grammes), the left 52 ozs. (1,472 grammes). Both were of large size. The right was so tightly adherent all round that it could not be separated with the fingers. The left, however, was separated without great difficulty, but was also adherent all round.

The left pleura was distinctly thickened, the right markedly so.

On section both lungs were practically solid throughout, with the exception of a small portion at each base; but the right lung was more affected than the left. At the apices were several cavities of rather large size, 3 to 4 cm. in diameter; elsewhere were numerous smaller cavities, all with smooth walls and con-

taining yellow pus. Owing to the numerous white caseous foci, sections of the lung had the appearance of gray marble. Many bronchi contained pus, and had a thick red mucous membrane. All the peribronchial glands were enlarged, but they were free from caseation.

There was a moderate excess of pericardial fluid, but no signs of inflammation. The heart weighed 8½ ozs. (240 grammes); it was of normal shape and its muscle was healthy. Both auricles and the right ventricle were full of blood clot. The valves and aorta were normal.

Abdomen.—Peritoneum normal.

Liver weighed 49 ozs. (1,306 grammes). It was slightly paler and softer than natural.

Spleen weighed 5 ozs. (141 grammes), and was rather firmly adherent to the diaphragm. Its substance was abnormally pale.

Kidneys weighed 5 ozs. (141 grammes) and 4½ ozs. (127 grammes) respectively. The capsule peeled cleanly, but the substance was somewhat pale and soft.

Suprarenal capsules, stomach and pancreas were normal.

The jejunum was healthy, but scattered along the ileum was a number of recently-formed, rather small, tubercular ulcers. In the lower two or three feet of the ileum the mucous membrane was in addition reddened, and thickened universally, and the subperitoneal vessels were injected. There was no tubercular ulceration in the large intestine, but in the ascending colon, sigmoid flexure and rectum were numerous simple erosions of the mucosa, occurring in anastomosing lines and circles, such as are often seen in non-tubercular wasted subjects. This condition probably accounted to a large extent for the diarrhœa from which this patient suffered. The fæces were yellow and soft, and the mesenteric glands moderately swollen.

The bladder, penis, testicles, &c., were healthy.

Microscopic Examination.

(*a*) *Posterior Root Ganglia.*

Method of examination.—The 3rd, 4th, 5th, 6th and 7th dorsal ganglia of both sides were all hardened in formalin 5 per cent.; some of these were stained *en bloc* in a mixture of osmic acid 2 per cent. 4 parts, and acetic acid 1 per cent. 1 part, were cut in paraffin and then differentiated as in the method of Pal. Others were cut on a freezing microtome and the sections mordanted in iron alum 2 per cent., stained and differentiated in the solutions of hæmatoxylin and sulphurous acid respectively, used in the method of Pal, and finally counter-stained with alum carmine.

Both these methods display the medullated nerve fibres in a most satisfactory manner.

Dorsal 6. *Right.*—This ganglion was prepared by the second method mentioned above, batches of eight to ten sections being treated at a time and mounted in successive order (plate 6, fig. 2.)

The first few sections show the anterior and posterior roots immediately central to the ganglion. The latter root is composed of two bundles of unequal size, having diameters of ·680 and ·840 mm. respectively. The smaller of these bundles does not contain half the number of nerve-fibres it should and is obviously sclerosed. The anterior root is normal and there is no indication of inflammation in the tissues investing either root.

Nearer to the ganglion the larger of the two posterior root bundles splits into two, while the diseased one remains undivided.

In sections showing the beginning of the ganglion there is no difficulty in following the above-mentioned sclerosed fasciculus; it lies at one side of the field close under the sheath of the ganglion, not far removed from the anterior root. A little further on it can be traced into a focal lesion in the ganglion, which in parts where it is best developed, viz., just distal to the centre of the ganglion, has the following characters. It is recognised as a pale-stained field, occupying about one-sixth of the superficial area of the section and lying immediately below the ganglionic sheath. It extends inwards for a depth of ·595 mm., has an average transverse measurement of ·765 mm., and runs along the circumference under the sheath of the ganglion for a distance of about 1·190 mm. In structure it is composed of a mass of fibro-cellular material, in which the nuclear elements are either round or of elongated form and the fibrous elements irregularly disposed, and it is comparatively rich in blood-vessels, but the most important feature of the area is that hardly a nerve-cell or nerve-fibre of any kind is to be seen in it, showing that the lesion in the first place was of a destructive nature. The periganglionic sheath covering this area is two or three times thicker than normal; it retains its lamellated character but is over-cellular, small round cells being especially numerous on its inner surface. The remainder of the field at this level has a normal appearance, nerve-cells and fibres being present in abundance, and the dividing line between healthy and diseased parts is fairly sharply defined.

Changes like those above described are recognisable in about thirty-five successive sections, and in the sections distal to the lesion a sclerosed area takes its place, which is traceable into the peripheral nerve.

Immediately distal to the ganglion sections show four main bundles of nerve-fibres; one of these is the motor root and the other three constitute the sensory portion of the trunk, and of the latter one fairly large fasciculus, measuring 1·190 by ·765 mm., is severely diseased, being principally composed of fibro-cellular tissue which has clearly taken the place of nerve-fibres. A little further along this sclerosed fasciculus breaks up into

three small bundles, and in the end all the above bundles, normal and diseased (including the anterior root) fuse and become surrounded by a common perineurium, but the sclerosed bundle can still be seen lying at one side of the field.

The continuation of the change is described under the heading "*Peripheral nerves.*"

Dorsal 6. *Left.*—The roots seen immediately central to the ganglion are composed of normally stocked fasciculi of nerve-fibres, the ganglionic body is free from focal lesion and the first part of the conjoint nerve-trunk shows no trace of sclerosis.

Dorsal 3, 4, 5, 7 *and* 8. *Right and Left.*—Show no noteworthy change.

(*b*) *Posterior Spinal Nerve-roots.*

Method of examination.—After hardening in formol 5 per cent., the roots were placed for several days in a mixture of four parts of osmic acid 2 per cent., and one part of acetic acid 1 per cent., and were then cut in paraffin. Differentiation when necessary was effected with the solutions employed in Pal's original process for staining medullated nerve-fibres.

By this process the medullated sheath of nerve-fibres of all calibres stains jet black.

Dorsal 6. *Right and left.*—In transverse sections of the root of the right side, two small bundles are seen lying together at one end of the section which are undoubtedly sclerosed, but the number of fibres which have disappeared does not look so great as was expected. However, on comparing the sections of this root with those of the root of the opposite side, one immediately notices that the former is much the smaller of the two, and all things considered, we think it not unreasonable to assume that this root was originally the seat of herpetic degeneration, but on account of the great length of time which has elapsed since the attack of herpes, a considerable amount of contraction has occurred, and this, by diminishing the area of the field of sclerosis, masks and gives a false conception of the actual number of fibres which have been destroyed and absorbed. In the remaining bundles spaces are present which suggest sclerosis.

The root of the left side is normally stocked with healthy fibres. In both roots fibres of large and small calibre are noticeable.

Examination of the 3rd, 4th, 5th, 7th and 8th dorsal roots of both sides gives negative results.

(*c*) *Peripheral Nerves.*

Method of examination.—Same as for the posterior roots.

Dorsal 6. *Right.*—Transverse sections made at a point about 1 cm. distal to the ganglion show that the nerve is composed

of five fasciculi, all of approximately equal size, and of these one is seriously diseased. It lies at one end of the section, has a diameter of ·340 mm., and is to a great extent deprived of nerve-fibres, a rough count showing that there are only about 170 fibres present, whereas there is room for six times that number. The fibres which remain are of all calibres, ranging from the ordinary large medullated fibre typical of the peripheral nerve, down through all sizes to the smallest tubule, and the latter are not grouped together in any special manner.

The tissue which has taken the place of the nerve-fibres is of fibrous character, staining of a pale brown tint like the perineurium.

Of the remaining fasciculi one has obviously lost a considerable number of fibres, but of the other three it can only be said that they do not contain quite their normal number.

The perineurium is not altered in any way, either locally or generally, but the blood-vessels which run in it are congested.

In sections about 2 cm. distal to the ganglion the nerve is split up into ten different fasciculi of varying sizes, and of these three bundles lying at one end of the section are undoubtedly deficient in nerve-fibres, and some of the others do not contain their normal number.

In sections about 3 cm. distal to the ganglion the bundles are all smaller and more approximately of equal size. A deficiency in fibres in some of the fasciculi is still noticeable.

In sections 4 cm. distal to the ganglion the nerve is composed of eight fasciculi; of these three fairly large bundles with an average diameter of ·510 mm. lying at one end are fairly healthy. The remaining five bundles, which have an average diameter of ·250 mm., are all sclerosed, and two lying quite at the edge of the section are peculiar in that the fibres which remain are all large, round and swollen, and instead of showing a ring of myelin they stain a uniform jet-black throughout.

In sections 7 cm. distal from the ganglion the nerve consists of one corporate bundle with a diameter of about ·765 mm., in the sheath of which runs a single tiny fasciculus. At one end of this large bundle is an obvious patch of sclerosis involving about one-sixth of its superficial area.

Most of these changes in the peripheral nerve are clearly displayed in the accompanying illustrations, which have been made with an Abbé drawing apparatus, each nerve-fibre being placed in its correct position (plate 16, figs. 3, 4, 5).

Dorsal 6. *Left* (1 *cm. distal to the ganglion*).—This nerve also is composed of five fasciculi all of approximately equal size, and it may be at once stated that no bundle shows any alteration which can be compared with that described as existing in the corresponding portion of the right nerve, but at the same time there are minute spaces scattered about which seem to indicate that a few fibres are wanting. This appearance was also noted in the healthy bundles of the right nerve. There is again no

perineural thickening, and the vessels accompanying the nerve are only moderately congested.

Sections about 2 cm. distal to the ganglion show one large, three medium sized, three small and two minute bundles; in none of these is there any pronounced morbid alteration, and the same remarks apply to other sections made at further distal points.

Dorsal 3, 4, 5, 7 *and* 8. *Right and left.*—Show no noteworthy change.

(*d*) *Spinal Cord.*

Method of examination.—One segment only, viz., the 4th dorsal, was stained by the method of Marchi (Orr's modification). The remainder of the cord was hardened in formalin 5 per cent., and sections from various levels were stained with osmic acid and hæmatoxylin by a process which displays medullated nerve-fibres.

Dorsal 4.—As death occurred so long after the herpetic eruption, it was thought that nothing would be gained by examining the cord by the method of Marchi, because traces of acute degeneration which might have been present at an earlier stage would now be absorbed. The sections from this segment prove the correctness of this assumption, for no degenerated products whatever are recognisable in the position in the posterior column which the fibres of the 6th dorsal root of the right side occupy, or indeed in that neighbourhood; but at the bottom of the postero-internal column of the left side, lying close up to the posterior commissure and extending backwards more than half-way up the posterior median septum in the form of a tapering line, the method reveals a curious collection of acutely degenerated fibres, the significance of which is entirely problematical. It is now to be regretted that the cord above and below this level was not examined by the method of Marchi, so that the origin, further course, and destination of these fibres might have been traced.

Also in the left lateral column, scattered about in the direct cerebellar and antero-lateral cerebellar tracts, are some few degenerated fibres, the presence of which is likewise unexplained.

Sections from the 7th cervical to the 3rd dorsal and from the 5th to the 8th dorsal segments inclusive, which were stained to display medullated nerve-fibres, show no definite sign of sclerosis in the posterior columns, and no other pathological change whatever.

The absence of sclerosis in that part of the posterior columns occupied by the fibres of the 6th dorsal root of the right side, proves that post-herpetic spinal degeneration, though plain enough when examined in an early stage by the method of Marchi, is not sufficiently copious to leave behind a recognisable tract of sclerosis after the products of degeneration have been absorbed.

Case 14.—Sydney Herbert B., aged 40. Admitted to the London Hospital (Mr. Jonathan Hutchinson) May 21, 1898. Died July 24, 1898.

SUMMARY.

He suffered from lymphatic sarcoma involving the glands of the neck, axillæ, and groins.

Sixteen days before death herpes zoster appeared over the 4th dorsal area of the right side (fig. 14).

On post-mortem examination many glands were found to be involved, including those of the anterior and posterior mediastinum and the glands on either side of the lumbar spine.

The growth situated on the anterior aspect of the spine in the upper dorsal region had passed in at the foramina, enveloping many of the ganglia and posterior roots on both sides.

On microscopical examination all the ganglia were free from growth, except the 4th dorsal on the right side, which was profoundly destroyed by the invasion of lympho-sarcomatous growth. But although the other ganglia had resisted invasion, the connective tissue around many of those in the upper dorsal region showed new growth in varying quantities, and several roots were affected over and above the 4th dorsal on the right side, which was profoundly degenerated.

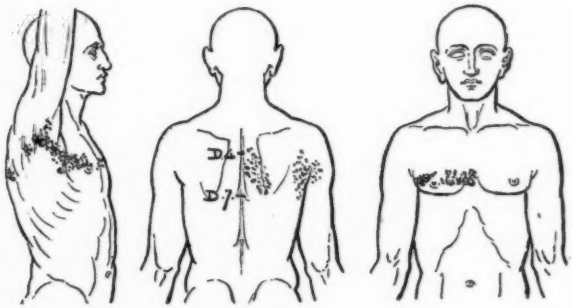

FIG. 14.

To show the distribution of the eruption in Case 14.

History.—He was quite well until six weeks before admission, when he began to feel pain under the shoulder-blades. He put on a mustard plaster, and in the morning the pain had left the shoulder and gone to the small of the back. He continued his work, but felt tired, and the pain in the back still troubled him. He stayed in bed for a couple of days, and then went away from

London. He then suffered greatly with pains everywhere, and could not sit or stand for any length of time. Two weeks before admission the glands in the neck began to swell, but caused no pain. Next the glands in the groin enlarged, and then those in the axilla. The glands were painless, but he suffered from general weakness and pain in the back. Ten days before admission the glands became tender, those in the groin being the worst.

He had always been healthy and strong, except that about three years ago he had some sores in the mouth which came and went in different places. He was put upon mercury, and the sores disappeared.

His mother died of cancer of the uterus, and maternal grandmother of cancer. There was no other family history of importance.

On admission, the glands in both axillæ and in the neck were much enlarged, more so on the left than the right side. The glands in the groin and popliteal spaces were also enlarged, but to a less degree.

There was considerable tenderness of the abdomen, in the region of the liver, and in the lumbar region, but the spleen and liver were not enlarged and nothing abnormal could be felt.

No abnormal physical signs were discovered in the chest.

Urine 1020; contained a small quantity of albumen, but no blood or casts.

His temperature was irregular, but rose to 101° F. (38·6° C.), and rarely fell below 100° F. (38° C.).

Progress.—On June 6 he complained of a sore throat. The left tonsil was inflamed and covered with slough.

Over the 5th rib on the right side, and a little inside the mid-axillary line, a hard lump about the size of a walnut had made its appearance. Other nodules appeared on the ribs, and increased in size and number.

The glands in the neck increased greatly in size, so that they formed almost a collar round the neck.

The tonsil sloughed and the whole tonsillar substance sloughed away.

July 8. He developed herpes zoster over the area in fig. 14, corresponding to and marking out the complete area of the 4th dorsal ganglion. The rash came out quite painlessly.

Rhonchi now began to appear in both lungs.

From this time onwards he wasted profoundly, had occasional attacks of diarrhœa and became very weak.

He died on July 24, seventeen days after the first appearance of the eruption.

Post-mortem Examination.

Twenty-four hours after death. Rigor mortis had passed off. Much wasting. Marked œdema of right leg.

The area that had been occupied by the herpetic eruption was still marked out at the *post mortem* by many scabbed patches.

Bunches of enlarged glands were present in both Scarpa's triangles and on both sides of the neck. They were large, freely movable and on section soft, of a grayish colour and showed no caseation.

The glands of the anterior mediastinum were matted together and invaded by new growth. They formed a large mass, 5 inches (12·5 cm.) from above downwards, 4 inches (10 cm.) from side to side, and $2\frac{1}{2}$ inches (6 cm.) at its thickest part. The growth invaded the upper part of the pericardium and the inner surface of the sternum, opposite the 3rd, 4th and 5th ribs.

There was some enlargement of the posterior mediastinal glands, and the anterior surface of the spine in the upper dorsal region was covered by new growth. This growth dipped into all the foramina.

When the spinal canal was opened from the back and the ganglia dissected for removal, this growth from the anterior surface of the spine was seen in close contact with the ganglia, especially from the 1st to the 5th dorsal. This growth seemed to lie in contact only with the 1st, 2nd and 3rd dorsal ganglia, so that when they were carefully removed the greater part of the growth remained behind in the canal. The 4th dorsal ganglion on the right side was, however, completely lost in the growth, and was therefore removed embedded in the contents of the foramen.

There were no secondary growths in the lungs.

Heart was normal.

In the abdomen there was extreme enlargement of the mesenteric glands, which entirely surrounded the aorta. A large mass of glands was situated over both iliacus muscles.

The spleen was large and soft, but contained no secondary deposits.

The capsule of the kidneys stripped easily, and on the surface were seen large numbers of whitish-gray masses of rounded shape. These secondary deposits were found, on section, to be diffused throughout the substance of the kidney.

The liver weighed 6 lbs. 2 ozs. (2·77 kgm.). Scattered throughout its whole substance were large white irregularly round secondary deposits. In the right lobe close to the surface was one large secondary nodule of about $1\frac{1}{2}$ inches (4 cm.) in diameter.

Microscopical Examination.

The following portions were examined microscopically:—(*a*) a series of posterior root ganglia, (*b*) a series of posterior roots, (*c*) the spinal cord.

(*a*) *Posterior Root Ganglia.*

The 1st, 2nd, 3rd, 4th, 5th, 6th and 7th posterior root ganglia on both sides were hardened in 96 per cent. alcohol

and cut in paraffin in longitudinal series. They were stained by Nissl's methylene blue method and counter-stained with safranin, erythrosin or eosin.

Dorsal 1. *Right.*—The actual ganglion itself is unaffected. The ganglion cells stain well and there is no increase of interstitial tissue and no invasion by small round cells. The capsule is intact, but outside in the periganglionic tissue is a mass of new growth, composed of small round cells that take the blue extremely deeply. These cells lie in spaces resembling those of a lymphatic gland, and the growth is evidently a lymphatic sarcoma.

Dorsal 1. *Left.*—This ganglion closely resembles that on the right side. The growth can be seen around the ganglion, but it has not penetrated the sheath, which is clean and smooth.

Dorsal 2. *Right and left.*—Around both these ganglia a large mass of new growth is visible, but the ganglia themselves show no signs of invasion or of secondary inflammation. The cells stain well.

Dorsal 3. *Right and left.*—On both sides the amount of growth is less and in neither ganglion has the growth penetrated the capsule or caused secondary inflammation.

Dorsal 4. *Right.*—This ganglion shows a completely different condition (plate 2, figs. 1 and 2); for here the thick fibrous sheath of the ganglion has been penetrated by new growth which has involved the ganglionic substance. The space inside the sheath is occupied by a multitude of small round cells that stain extremely deeply with methylene blue. Here and there the remains of ganglion cells can be seen as white or greenish-blue discs with an unstained nucleus. In those specimens where the ganglion has been counterstained with erythrosin, these ganglion cells appear as pink undifferentiated bodies surrounded by masses of small round cells of a deep blue colour. When the inflammation is less intense the ganglion cells stain as uniform blue masses. The more outlying cells show marked chromatolytic changes, Nissl's particles have disappeared, the body of the cell presents a uniform granular appearance, and large light patches are seen in its protoplasm. The nucleus of these cells is excentric, and appear in some cases to have been extruded.

Dorsal 4. *Left.*—Some new growth can be seen in the connective tissue surrounding this ganglion, but it has not penetrated the sheath, and within the substance of the ganglion neither nerve-cells nor interstitial tissue show any change.

Dorsal 5. *Right.*—The ganglion is normal and has not been invaded by the growth which is seen in the surrounding connective tissue.

Dorsal 5. *Left.*—No growth seen. Ganglion normal.

Dorsal 6. *Right.*—No growth seen in the tissue surrounding the ganglion. Ganglionic substance normal.

Dorsal 6. *Left.*—Growth is seen in the connective tissue surrounding the extreme peripheral end of the ganglion. The ganglionic substance is normal.

Dorsal 7. *Right.*—A small amount of new growth is seen surrounding that part where the peripheral nerve gives off its posterior primary division. This growth passes inwards towards the ganglion lying along the side opposite to the anterior root. The ganglionic substance is normal.

Dorsal 7. *Left.*—No growth seen. Ganglion normal.

(*b*) *Posterior Nerve-roots.*

The 2nd, 3rd, and 4th dorsal nerve-roots on the right side all show some degenerated fibres by Marchi's method, but the most marked degeneration is seen in that of the 4th dorsal corresponding to the ganglion that has been destroyed by the new growth. On the left side the 2nd and 3rd dorsal show a slight amount of degeneration, but much less in extent than that in any of the roots of the right side. The 4th dorsal on the left side is normal, and the 5th dorsal on both sides is unaffected.

It must be remembered that although only the 4th dorsal ganglion on the right side was invaded by the new growth, some new growth was seen in most of the foramina surrounding the ganglion and passing inwards with many of the posterior roots. To this must be attributed the degeneration of many roots, although one ganglion only is actually involved.

(*c*) *Spinal Cord.*

The spinal cord was hardened in Müller's fluid, cut, and stained by Marchi's method. Unfortunately, owing to the degeneration of many nerve-roots, the changes in the spinal cord are of but little value from the point of view of localisation. For in the lower lumbar region the cord shows a mass of degenerated fibres in the posterior columns, due to the infiltration of nerve-roots by the lumbar focus of growth (*vide supra* page 480). This degeneration is seen passing up the cord, and at the region of the 6th dorsal has become entirely confined to Goll's column on both sides.

At the level of the 4th dorsal an extremely marked mass of degeneration is seen to enter the cord with the 4th dorsal root on the right side and to occupy the root zone. At the level of the 3rd dorsal this degeneration is extremely marked, and is apparently reinforced by fibres from the 3rd dorsal root. On the left side at this level there are possibly a few degenerated fibres amongst those entering in the posterior root, but the picture presented bears no relation in intensity to that in the root zone of the right side. The entry of acutely degenerated fibres seems to cease at the level of the 1st dorsal, and the degenerated fibres from the 4th, 3rd, 2nd, and 1st dorsal roots take up a position in the postero-external column and can be traced up to the posterior column nuclei.

Case 15.—William H., aged 36. Admitted to the London Hospital under Mr. Moullin, January 26, and died February 13, 1899.

SUMMARY.

On January 26 *he was struck on the back by a descending lift. He was absolutely paralysed below the umbilicus, and sensation to all forms was abolished below the lower border of the* 9*th dorsal segment. Above this level there was a zone of hyperalgesia occupying the* 7*th,* 8*th and* 9*th dorsal areas. The knee-jerks and plantar reflexes were absent.*

February 7. *A small patch of herpes appeared over the* 9*th intercostal space on the left side, close to the tip of the* 9*th and* 10*th rib cartilages.*

He died on February 13, *six days after the development of the eruption and eighteen days after the accident.*

On post-mortem *examination the* 11*th dorsal vertebra was found to have been fractured and the* 11*th and* 12*th vertebræ had gone bodily backwards. A portion of the intervertebral disc between the* 11*th and* 12*th dorsal projected into the spinal canal, cutting the cord like a knife.*

On microscopical examination three separate conditions were found, corresponding with (1) *the direct injury,* (2) *the secondary vascular disturbance,* (3) *the herpetic eruption.*

(1) *The spinal cord was completely divided at the level of the* 1*st lumbar segment. The* 11*th and* 12*th segments also showed hæmorrhages and some infiltration with small round cells. The* 10*th dorsal segment was unaffected by the direct injury, but here and in every segment above, the cord showed the usual ascending degeneration in the posterior and antero-lateral columns.*

The roots of the 10*th and* 11*th dorsal were torn through close to their exit from the ganglion. These ganglia and the portions of the roots attached to them were surrounded by a mass of inflammatory tissue.*

(2) *The cells of all the ganglia examined showed extremely marked chromatolytic changes; Nissl's granules were diminished, the nucleus was excentric and in many places had been extruded. These changes were present even in the* 8*th and* 9*th ganglia, which were entirely free from surrounding inflammation.*

The posterior roots of the 7*th,* 8*th,* 9*th,* 10*th and* 11*th dorsal were more or less congested and showed swelling of the medullary sheath and invasion by leucocytes. These leucocytes contained much material that stained black with osmic acid.*

The whole of these changes are probably due to vascular changes secondary to the injury, and the changes in the ganglion cells are probably associated with the area of hyperæsthesia over the 7*th,* 8*th and* 9*th dorsal areas.*

(3) *The* 9*th dorsal ganglion on the left side showed a small focus of round-celled infiltration. It was the only ganglion that*

showed any such change, and this, taken in connection with other cases, may probably be assumed to be the cause of the eruption of herpes over the tip of the 9th intercostal space.

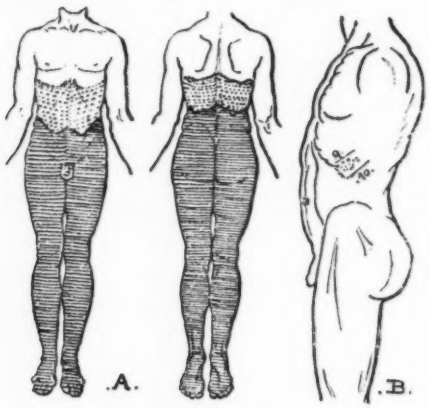

FIG. 15.

A.—To show the area of altered sensation in Case 15. The complete analgesia is represented by horizontal lines, the hyperalgesia by dots.
B.—To show the area occupied by the herpetic eruption in the same case.

History.—At 5.30 a.m. on January 26, he was adjusting the buffers of a lift when it came down, striking him on the back.

On admission.—He was absolutely paralysed in his lower limbs. The muscles of the abdomen about 1½ inches (4 cm.) below the umbilicus were relaxed and flabby, whilst those of the upper abdomen were tense and contracted. Sensation to touch, pain, heat and cold was absolutely abolished above the upper level of the 10th dorsal segment, and the upper level of the loss of sensation was sharply marked, scarcely varying half an inch (1·3 cm.) on repeated testing. Above this level was an area of marked hyperalgesia to all forms of stimulation. Within this band touch, heat and cold all gave him pain, and a moderately painful stimulus became intensely so (fig. 15A).

The knee-jerks were absent on both sides; plantar reflexes absent. The abdominal reflexes were abolished below the level of the umbilicus, but above the umbilicus over the hyperæsthetic area they were distinctly increased.

He had complete retention of urine, and his penis was turgid and semi-erect.

There was a large bruise in the mid-dorsal region over the left side of the spine from above the level of the 8th to the 12th dorsal spine. Several ribs were fractured on the left side.

Progress.—On January 29, the urine became alkaline and remained so until Feb. 5.

On February 7, a small patch of herpetic eruption appeared on the left side over the tip of the 10th rib. It consisted of two small groups, one of twelve vesicles situated over the extreme anterior portion of the 9th space, and a second small group of five vesicles situated over the tip and posterior border of the 10th rib. There was no redness around, and the whole eruption was extremely slight.

His temperature showed an irregular rise and fall, sometimes reaching 102° F. (39° C.), but usually ranging between normal and about 101° F. (38·4° C.). Râles appeared all over the chest, and he died on the early morning of February 13.

Post-mortem Examination.

Made ten hours after death on February 13.

Rigor mortis well marked. No bed sores. Two small patches of herpes were still present over the tip of the 10th rib. No further patches anywhere.

There was a marked projection of the spine in the extreme lower dorsal regions, and on removing the skin the 11th dorsal was found to be the highest vertebra involved in the projecting mass. The spine of the 10th dorsal vertebra was loose and could be moved without difficulty. The transverse processes of the 11th dorsal vertebra were fractured, and permitted movement of the spine in an antero-posterior direction.

On removing the laminæ the 11th and 12th dorsal vertebræ were found to have gone bodily backwards. A portion of the intervertebral disc between the bodies of the 10th and 11th dorsal vertebræ was loosened, and had been forced backwards so as to project, cutting into the cord like the blade of a knife at a level just below the entry of the 11th root into the cord.

At this point the theca was dark red, much swollen and thickened from inflammatory tissue. On the right side the 11th dorsal ganglion was involved in a dense mass of fibrous tissue. From the point where the 10th dorsal root entered the cord on either side the cord was brown and diffluent. At the level of entry of the 11th root it was universally softened, so that the pia-arachnoid contained nothing but blood-stained débris.

The 10th and 11th ribs on the left side had been fractured but had united again, with the formation of a good deal of callus. The point of fracture of the 10th rib was about two inches from its head.

There was a good deal of recent lymph over the base of the left lung. The lower lobe of the left lung was solid. The upper lobe was normal, except for slight bronchitis. The whole upper lobe of the right lung was universally adherent by old adhesions.

Heart, normal.

Liver, large, somewhat fatty.
Spleen, normal.
Kidneys: Capsule stripped with some difficulty. Both kidneys somewhat congested, but otherwise normal.

Microscopical Examination.

(*a*) A series of posterior root ganglia, (*b*) a series of posterior roots, (*c*) the spinal cord.

(*a*) *Posterior Root Ganglia.*

The ganglia were hardened in 96 per cent. alcohol, embedded in paraffin, and cut longitudinally in series. They were stained by Nissl's method and certain series were counterstained with safranin or with eosin.

Dorsal 8.—Both the ganglion of the right and left side show the same changes, and can therefore be described together. There is no thickening or inflammation of the sheath and no infiltration by small round cells in its substance. The vessels are not engorged and there are no hæmorrhages.

But on the other hand the ganglion cells have undergone remarkable changes. In some the Nissl granules are markedly diminished, in others unstained areas are visible. In many the nucleus is excentric, and in some it appears to have been extruded. In such cases the cells are irregular in shape and contain few Nissl-bodies. Thus the ganglion cells of all forms have undergone marked chromatolytic changes.

Dorsal 9. *Left.*—Here the cells have undergone a similar change to that described above, but in addition there is a small focus of small round cells, obviously of inflammatory origin. These cells stain more darkly with methylene blue than the cells of the normal interstitial tissue. There is no sign of a hæmorrhage. If we consider the slightness of the herpetic eruption, we cannot wonder that the amount of inflammatory change was less than in previous cases.

Dorsal 9. *Right.*—This ganglion shows no inflammatory change of any kind; but, just as in all the other ganglia, the ganglion cells show marked chromatolytic changes.

Dorsal 10. *Left.*—This ganglion lay below the fractured vertebra and represents the highest level of the analgesia (*vide* fig. 15A). Under a low power the most marked microscopical feature is the mass of inflammatory tissue that surrounds the posterior root and central portion of the ganglion. The ganglion lies embedded in this tissue like the stone of a fruit. Just central to the ganglion the posterior root fibrils are reduced to a mass of disorganised tissue surrounded by effused blood and inflammatory tissue. Yet, in spite of these profound changes around the ganglion, the sheath has remained intact. The interstitial tissue is

quite unaltered, and there is no destruction of ganglion cells from without. But, as elsewhere, the cells themselves show marked chromatolytic changes. These range from rarefaction of the granular staining material to extrusion of the nucleus, with shrivelling of the body of the cell.

Dorsal 10. *Right.*—The destructive process around the ganglion and in the posterior root fibres is not quite so profound as on the other side. But in nature the changes are identical, and here again the sheath of the ganglion has formed a complete barrier to invasion by the inflammatory process.

The peripheral nerve entering both the right and left ganglion is unaffected.

Dorsal 11.—Both left and right ganglia at this level show similar changes. The posterior roots, just after they have left the ganglion, are severed, and the remains embedded in a mass of inflammatory tissue and altered blood. In no case is there the slightest evidence of inflammation within the substance of the ganglia themselves. The cells of both ganglia exhibit profound chromatolytic changes.

The peripheral nerve as it enters the ganglion is in both cases unaltered.

(*b*) *Posterior Nerve-roots.*

The posterior roots were hardened in Müller's fluid and stained by Marchi's method. They were embedded in celloidin and cut strictly longitudinally.

Dorsal 11. *Right and left.*—The fibres of both these roots are swollen and the myelin sheath is in many places interrupted. But the most marked change is the enormous number of leucocytes of all sizes which lie between the fibres. These cells contain large masses of darkly-staining fat or darkly-staining granules. In many places the fibres show marked erosion, and in some places have nearly disappeared under the eroding action of these leucocytes. The vessels are much engorged with blood.

The condition of these roots is unlike that of roots that are undergoing acute degeneration, and the changes they exhibit are probably due to the fact that they were destroyed at the time of the accident. Thus, although the patient lived for a considerable time after the accident, the roots being necrosed could not degenerate, whilst the interstitial tissue would show absorptive changes to an even more marked degree than usual.

Dorsal 10. *Right and left.*—Both these roots show an exactly similar change, but the changes are less marked on the right side than on the left.

Dorsal 9. *Left.*—There is less swelling of the fibres, but the invasion of leucocytes containing particles that stain with osmic acid is extremely marked.

Dorsal 9. *Right.*—This root on the other hand shows no definite change.

Dorsal 8. *Left.*—In parts this root is normal. Then in other parts patches are seen where the above-mentioned changes are visible.

Dorsal 8. *Right.*—Here the change is extremely marked. The central vessel is gorged with blood and all its collateral branches stand out full of blood.

Dorsal 7. *Left.*—This root contains two groups of rootlets. In one of them the vascular engorgement is very marked, and here the above-mentioned changes are present to a marked degree. In the other the vascular disturbance, if present, is slight, and here the swelling of nerve-fibres and leucocytosis is absent.

Dorsal 7. *Right.*—On the whole this root is more normal than that of the other side, but in places the same changes can be seen as in the left root.

Thus the posterior nerve-roots show two changes in this case. Firstly, the 10th and 11th roots on both sides are crushed close to their exit from the ganglion to such an extent that they are practically divided. Here the roots are surrounded by a mass of inflammatory tissue as far as they lie in the canal. The 7th, 8th and 9th roots on the other hand are not divided or crushed, and are not surrounded by inflammatory tissue.

Secondly, all the roots to a varying degree exhibit some changes in the nerve-fibres. They do not show the long bead-like rows of black dots usually seen by Marchi's method in an acutely degenerated nerve. The change consists mainly of a marked swelling of the sheath with erosion and disappearance in parts, accompanied by an invasion of leucocytes of all sizes. These leucocytes are crowded with particles that stain black with osmic acid. Wherever this change occurs in the 7th, 8th and 9th dorsal roots the vessels are engorged, and even the smallest branches are filled with blood.

(*c*) *Spinal Cord.*

The spinal cord was hardened in Müller's fluid, and the 7th, 8th and 9th segments were in part stained with carminate of soda, in part by Marchi's method. The cervical and upper dorsal regions were also stained by Marchi's method. The 11th and 12th dorsal and lumbar cord were cut unstained and then treated with hæmatoxylin and eosin.

From the 2nd dorsal segment upwards the cord shows the typical ascending degeneration, caused by a transverse lesion in the lower dorsal region. The whole of the postero-median (Goll's) column is occupied by degeneration. Degenerated fibres are also seen in the antero-lateral ascending tract on both sides.

Passing downwards the degenerated fibres occupy more of the posterior columns in the usual manner. At the level of entry of the 9th dorsal roots masses of degenerated fibres are seen lying close to the posterior horn on both sides, but the entering roots of the 7th, 8th and 9th dorsal show no acute degeneration.

The 7th, 8th, 9th and 10th segments show no change either by carmine or hæmatoxylin and eosin, but at the level of the 11th dorsal the first signs of traumatic change become visible. Here a small hæmorrhage is visible in the lateral columns close to the posterior horn. Scattered about the cord are many small foci of small round-celled infiltration.

At the level of dorsal 12 the blood clot has expanded into a hæmorrhage destroying one-third of the cord. This hæmorrhage is surrounded by small round cells and the whole cord stains badly, as is usual in these traumatic cases in the neighbourhood of the injury.

At the level of lumbar 1 the cord is completely cut in two, and at the point of division lies a large hæmorrhage in a mass of new tissue.

The remainder of the cord is disorganised and consists of broken down débris enclosed by the pia-arachnoid and some inflammatory tissue.

Case 16.—Amy C., aged 25, admitted to Guy's Hospital December 6, 1897. Died May 28, 1898. (Dr. Pye-Smith.)

SUMMARY.

This patient suffered from a form of meningo-myelitis and multiple sclerosis, secondary to endarteritis obliterans.

In the summer of 1894 *she lost power in the right leg and sight in the right eye. She recovered in six months, except for a little weakness of the left ankle, which came on insidiously during the recovery of the right leg. Then she lost power over micturition. December* 4, 1897, *suddenly lost power in both legs.*

On admission all sensation was lost below the umbilicus, and both legs were paralysed. Complete incontinence of urine and fæces.

February 21, 1898. *She developed an attack of herpes zoster over the area in fig.* 16, *corresponding to the* 3*rd cervical.*

Motion and sensation somewhat improved; but cystitis reappeared and she died on May 28, *after giving birth to a seven-months' child, ninety-six days after the attack of herpes zoster.*

Post-mortem *examination showed no changes of importance in the abdominal and thoracic viscera, except the signs of old cystitis and secondary abscesses in the kidneys.*

The medulla and spinal cord showed wide-spread sclerosis with acute degeneration around the free border of the sclerotic patches. At the level of the 7*th and* 8*th dorsal the cord was necrosed over rather more than one-half of its extent. There was distinct meningitis and the vessels showed marked signs of endarteritis obliterans.*

In connection with the herpetic eruption the 3*rd cervical gan-*

glion of the left side showed multiple foci of small round-celled infiltration, and the intramedullary portion of the 3rd cervical root was acutely degenerated. The extramedullary roots all showed a curious change, but there was no lesion in them that could be definitely attributed to the herpetic foci in the ganglion.

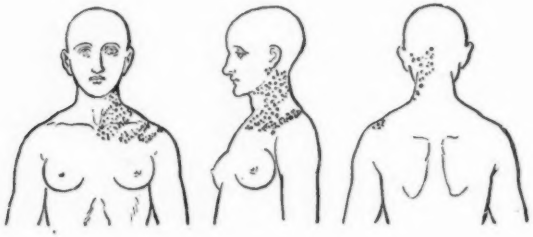

FIG. 16.

To show the distribution of the eruption in Case 16.

History.—In the summer of 1894 she was seized with shivering whilst out walking one evening, and for the next two days suffered from headache, languor and depression. On the third day she found that her right leg was weak, cold and seemed to have lost feeling. Next morning the leg was absolutely paralysed. She remained in bed three months, and during this time she gradually lost the sight of the right eye. Vision returned suddenly after three weeks, but she then saw objects double at a distance. At the end of three months she began to regain feeling in the right leg, and in six months from the onset was able to walk two or three miles.

During the early months of 1895 she was quite well, except that she noticed some weakness of the left ankle, that persisted up to admission.

For eighteen months before admission she had some difficulty in holding her water. This varied from day to day, and at times became complete incontinence.

With exception of the weakness of the left ankle and the difficulty in holding her water she remained well until December 4, 1897. At 5 p.m. on this day she came downstairs, and coming quickly into the room suddenly fell onto the floor, but did not hurt herself. She found she was quite unable to move her legs. She had no pain, but had lost all feeling in the legs.

She was brought to Guy's Hospital on December 6, 1897, and *on admission* her condition was as follows :—

She was a sallow, extremely dark-complexioned woman of 25. Bright and intelligent.

She lay in bed unable to move her legs or change her position, but she could use her arms.

Nervous system.—Speech unaffected. No headache. No fits. There was complete paralysis of both legs and of the lower part of the trunk, with spastic rigidity. No wasting or change in electrical reactions.

There was no weakness, tremor, or inco-ordination of the upper extremities. She could pick up a pin easily with either hand.

There was complete loss of touch, pain, heat, and cold in both legs and over the front of the abdomen up to a level about six inches above the umbilicus. Posteriorly the total anæsthesia and analgesia reached up to the level of the 11th dorsal spine. The upper level, both in front and behind, varied within considerable limits on different occasions. Above this area of lost sensation was a band of hyperæsthesia extending upwards to the level of the 5th space.

The knee-jerks were not obtained, and there was no ankle clonus. The elbow-jerks were present. The plantar reflexes were exaggerated and the right was greater than the left. The abdominal reflexes were not obtained.

The pupils reacted to light and accommodation. There was no ocular paralysis. The face moved well and equally. No difficulty in swallowing. The tongue moved well and was not wasted.

Hearing, smell, and taste were normal. The discs were said to be perfectly healthy.

She had lost all control over both urine and fæces.

The urine was acid and contained no albumen or sugar.

Progress.—On December 16 the knee-jerks were noticed to have returned, but there was no ankle clonus.

On February 21, 1898, she developed an attack of herpes zoster over the area in fig. 16. Owing to the kindness of Dr. Pye-Smith one of us was permitted to see her and to take full notes of her condition

At this time she showed complete spastic paraplegia of both legs and voluntary movement was impossible either at or below the hips. There was no loss of power in the arms or hands. No tremor or wasting.

On the right half of the body sensation to touch, pain, heat, and cold was absolutely lost up to a line corresponding to the upper border of the 7th dorsal area. On the left side light touch and pain stimuli were lost up to the lower border of the 9th dorsal, heat and cold up to the lower border of the 7th dorsal. On the left side the 8th and 9th dorsal areas were occupied by a band of hyperalgesia. Deep touch was present over the whole of the left side, even to the sole of the foot.

The knee-jerks were now enormously increased and well-marked ankle clonus was obtained on both sides. The plantar reflexes were increased.

The pupils reacted to light and accommodation and there was no ocular paralysis. Undoubted nystagmus was present when she looked to the left, but not when she looked upwards, downwards, or to the right. Movements of the face were good and the tongue was unaffected.

She complained that her vision was failing again, and the left disc was distinctly paler than the right, but not to an extent that could make the diagnosis of optic atrophy certain.

There was still complete loss of control over both urine and fæces.

On March 5 she could feel a faradic current on the lower part of the right abdomen and over the right thigh for the first time since admission. By March 21 she could move the left leg slightly, and touch could be felt all down the front of the left leg, but painful stimuli were not appreciated as before. By April 22 she could move both legs, and sensation had still further improved.

On May 27 she gave birth to a child weighing 2 lb. 2 oz. (1 kgm.), apparently a seven months' fœtus, which died the same night. She was much collapsed, refused food, and died on May 28, ninety-six days after the outbreak of herpes zoster.

Post-mortem Examination.

Owing to Dr. Perry's kindness, one of us was permitted to make an examination nineteen hours after death.

Marked scarring was present within the area that had been affected by the herpetic eruption, and some of the scars were still scaly.

Both pleural cavities were normal, and the lungs were healthy, except for some hypostatic pneumonia of the upper part of the lower lobe of the left lung.

The pericardium was normal. There was no abnormality in either the muscle or valves of the heart.

The liver was normal.

The spleen was normal.

The bladder showed signs of chronic cystitis, especially about its neck.

Both kidneys contained small secondary abscesses, but there was no marked pyelitis.

The uterus was enlarged and contained no remains of placenta. The placental site looked healthy.

The large vessels were healthy to the naked eye, but subsequent microscopic examination showed that the smaller vessels of the nervous system had undergone extensive changes. The smaller cerebral vessels were markedly thickened by overgrowth of the endothelium, and in places were almost obliterated by nodular thickening. The vessels of the cord, especially in the region of the necrotic area, showed distinct nodular endarteritis.

Examination of the Central Nervous System.

The brain showed no naked-eye abnormality. Horizontal and vertical sections failed to reveal any localised patches of softening.

The pons and cerebellum showed no marked changes.

On removing the spinal cord and medulla it was at once obvious that they were the seat of profound changes. The cord was diminished in size, especially in the mid-dorsal region, and pale yellowish-white streaks could be seen running longitudinally up and down the cord. This appearance was most evident to the naked eye in the centre of the posterior columns and in the posterior aspect of the lateral columns.

The posterior and anterior roots and the posterior root ganglia showed no naked-eye changes.

Microscopical Examination.

An examination was made of (*a*) a series of posterior root ganglia; (*b*) a series of posterior roots; (*c*) the spinal cord.

(*a*) *Posterior Root Ganglia.*

The ganglia were hardened in 96 per cent. alcohol, embedded in paraffin, and cut in series. The ganglion of the right and of the left side, at each level, were embedded in the same block and cut and stained together, so that each section of the paraffin block contained a section of the right and one of the left ganglion at the same level.

The sections were stained with methylene blue according to Nissl's method, and counterstained with erythrosin.

Cervical 2.—On neither side is there any change in the interstitial tissue, nor infiltration by small round cells. But on the other hand, the ganglion cells do not stain well with methylene blue. The cells are unaltered in shape and the nucleus is not excentric, but they show a tendency to pick up the erythrosin rather than the methylene blue. This tendency is perhaps more marked in the ganglion of the left than on the right side, but we do not consider it has any direct bearing on the herpetic lesion.

Cervical 3.—These ganglia were cut longitudinally.

Cervical 3. *Left.*—There is a remarkable difference between the condition of the interstitial tissue in the ganglion of the left and that of the right side. (Plate 4, figs. 1 and 2). Scattered throughout the ganglion of the left side are numerous foci of round cells which stain deeply with methylene blue. The ganglion cells stain less deeply on the left than on the right side. Thus, where the ganglion is under-stained with blue the ganglion cells are seen to have taken the erythrosin, and the only blue is seen in the still darkly-stained small round cells. In the neighbourhood of these foci of darkly-staining small round cells the ganglion cells do

not stain at all and in places appear to be disintegrated. They are not vacuolated, and the nucleus is not excentric, but they are in such a condition that the body of the cell and the nucleus stain red (with erythrosin), only the nucleolus taking the blue. No hæmorrhages are visible.

Cervical 3. *Right.*—The ganglion cells do not stain well with methylene blue, but there are no foci of darkly-staining small round cells, as on the left side.

Cervical 4.—On neither the right nor the left side is there any change in the interstitial tissue. In fact, these ganglia are normal, excepting that the ganglion cells do not stain well.

Cervical 5.—Both right and left ganglia are normal. The cells stain better than in the other ganglia and there is no interstitial change.

(*b*) *Posterior Nerve-roots.*

The roots of cervical 2, 3, 4 and 5, on both the right and left side, were hardened in Müller's fluid and stained by Marchi's method. They were then cut longitudinally. Several roots were also examined in the dorsal region by the same method.

None of them show any signs of acute degeneration by Marchi's method, but the fibres do not stain well. They are pale and ash-gray coloured, their outline is indistinct, and many of them are slightly swollen. The demarcation between axis cylinder and fibre is not clearly marked. Although none of them show clearly-marked Marchi's degeneration, leucocytes containing fat and many irregular fat globules are seen lying between the fibres.

These changes are not more evident in one root than in another, and bear no relation to the herpetic lesion. For they are equally present in the cervical roots and in those of the dorsal region.

Thus the changes in the posterior nerve-roots seem to depend on the general disease rather than on the herpetic lesion.

(*c*) *Spinal Cord.*[1]

The spinal cord was hardened in Müller's fluid and stained by the Marchi, Marchi-Pal, and Stroebe methods, and also with hæmatoxylin and eosin.

The condition of the spinal cord is best understood by beginning from below and working upwards.

At the region of the 4th lumbar a wedge of sclerosed tissue runs inwards on either side in the postero-lateral region of the cord. At the level of the 1st lumbar these areas have spread

[1] A full description of this case will be included by Mr. A. F. Tredgold in his paper on "Sclerosis of the Nervous System."

forwards and increased considerably in depth. They are accompanied by many degenerated fibres (Marchi) where they abut on the remainder of the cord. There is some scattered acute degeneration in the posterior columns.

At the level of the 8th dorsal the whole anterior portion of the cord is necrosed and converted into a mass of granular débris, in which can be seen the remains of thickened and blocked vessels. In that part of the cord which still remains partly recognisable large and dense patches of sclerosis can be seen. Yet even in this portion, profoundly degenerated as it is, Weigert's method shows a number of blue fibres between the sclerosed patches, showing that all continuity is not destroyed.

At the level of the 7th dorsal this process has gone even further. The whole anterior part of the cord is necrosed, and the thickened membrane enclosing the debris of corpuscles and broken-down nerve-fibres contains thickened vessels and distended lymphatics. One large vessel is completely blocked. But at this level there is a definite line of demarcation between the necrosed anterior portion and the sclerosed posterior and postero-lateral portions of the cord.

At the level of the 6th dorsal the cord is much diminished in size, but is not necrosed. Patches of sclerosis are seen in the posterior columns, the postero-lateral columns, and anterior columns. All these patches are surrounded by much acute degeneration (Marchi).

From the 4th dorsal upwards the cord has nearly regained its usual size, but the patches of sclerosis in the posterior columns and in the lateral columns are very prominent. That portion of Goll's column which is not sclerosed shows acute degeneration.

At the level of the 3rd cervical similar appearances are present, but there is a field of acute degeneration representing the incoming root on the left side.

Further up the cord, at the level of the 2nd and 1st cervical, this field is seen lying close to the posterior horn.

Thus, in conclusion, the spinal cord shows the following different conditions:—

(1) An acute necrosis secondary to vascular obliteration.

(2) Areas of sclerosis which are not confined to tracts, also apparently secondary to partial vascular occlusion.

(3) Areas of acute degeneration on the extending border of these patches.

(4) Possibly some ascending and descending degeneration secondary to the focus of almost complete transverse division (dorsal 7 and 8).

(5) Acute degeneration entering the cord with the 3rd cervical root, probably connected with the herpetic lesion of the 3rd cervical ganglion on the left side.

(6) Meningitis of the membranes surrounding the cord, particularly on the anterior surface. These thickened membranes contain obliterated, or partly obliterated, vessels.

Case 17.—Joseph W., aged 56. Admitted to Rainhill Asylum March 15, 1898. Died September 14, 1898.

SUMMARY.

Admitted for general paralysis of the insane.

On June 6, 1898, *herpes appeared over cutaneous area of* 8*th dorsal segment on the left side* (*fig.* 17).

Death took place from dysentery 100 *days afterwards.*

All the posterior root ganglia were healthy except the 8*th dorsal of the left side. In this ganglion the sheath was thickened and there was an inflammatory focus causing destruction of some few ganglion cells.*

The spinal cord showed the changes of early tabes. In addition a mass of acutely degenerated fibres entered the cord at the level of the 8*th dorsal root on the left side.*

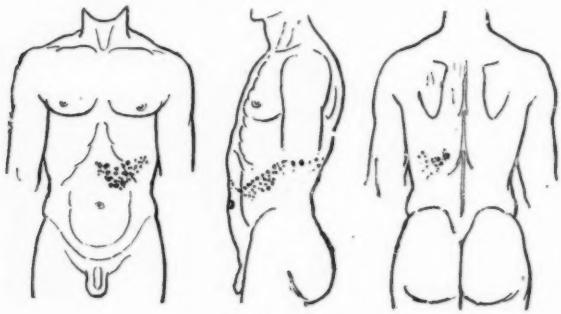

FIG. 17.

To show the distribution of the eruption in Case 17.

History.—Married; one still-born child and two which died when two days old. Syphilis admitted. Occupation, a marine engineer. Had had malaria in Africa several times. During the last three years had complained of general weakness and had twice been in hospital. Temperate as regards drink.

On admission.—Of slim build but fairly well nourished. No paralysis of motion or sensation. Speech clear and distinct. Gait good, but arm movements not under perfect control. Facial tremor. Knee-jerks absent. Superficial reflexes obtainable. Pupils small, but equal; they hardly reacted to light, if at all. Tongue protruded straight, almost free from tremor. Circulatory, respiratory, alimentary, and genito-urinary systems normal. General condition fair. Mentally restless, interfering, talkative, and the subject of grandiose delusions.

Progress.—June 6, 1898. Developed a mild herpetic eruption on skin of trunk, in region indicated (fig. 17). The vesicles were all of small size and were not numerous anywhere; there was practically no erythema and no constitutional disturbance.

June 13, 1898. Some of the vesicles had disappeared, some were scabbing, and others were pustular.

July 1, 1898. The eruption had disappeared and left but slight pigmentation.

He deteriorated mentally and physically, and on August 17, 1898, had several seizures of a mild type in rapid succession.

September 1, 1898. Developed dysenteric diarrhœa with pyrexia and prostration. This resisted treatment, and he died September 14, 1898, 100 days after the appearance of the eruption.

Post-mortem Examination.

Examination twenty-one hours after death. Warm weather.

Tall, slim frame, poor musculature. Just a trace of brown pigmentation over area where the herpetic eruption had been distributed. Skin otherwise clean.

Scalp and cranium normal.

Dura mater slack frontally, not thickened nor adherent. Sinuses partly filled with blood clot. Subdural fluid greatly in excess, no blood or membrane. Larger arteries sclerosed.

Pronounced general arachnoid opacity, Pacchionian bodies slightly enlarged.

Pia mater distinctly thickened and moderately hyperæmic; it stripped in one sheet, but tended to cling in the sulci. No decortication.

Cerebral hemispheres of fair size and symmetrical. Indications of general atrophy. Sulci wide.

Right hemisphere unstripped weighed 592 grammes, left hemisphere 607.

Cortex dark, hyperæmic, thin; striation indistinct.

White matter normal. General consistence firm.

Lateral ventricles enlarged, fluid in excess, ependyma granular.

Basal nuclei healthy to naked eye.

Cerebellum weighed 140 grammes. Cortex dark and thin.

Pons and medulla together weighed 35 grammes. No focal lesions. Ependyma of 4th ventricle granular.

Pituitary body, pineal gland, cranial nerves, &c., healthy to naked eye.

Vertebræ normal.

Fluid in spinal canal in excess.

The spinal pia-arachnoid was thicker than normal all along, but this was particularly marked on the dorsal aspect of the cord. Furthermore, there were firm fibrous adhesions between the dura mater and the pia-arachnoid, covering that length of cord which lay between the levels of origin of the 3rd and 11th dorsal

nerves. This was entirely confined to the dorsal side; there were no adhesions worth mentioning on the ventral aspect. Sections of the spinal cord revealed no macroscopic abnormality.

A series of posterior root ganglia and spinal nerves which were extracted also looked healthy to the naked eye.

Old fibrous adhesions were present round the upper lobe of right lung. Emphysema anteriorly in both, and on section general œdema and congestion, with a few patches of lobular pneumonia posteriorly. Bronchi congested.

Pericardium healthy. Epicardium dull gray in colour. Muscle dark and firm. No organic valvular disease.

Peritoneum normal. Liver of normal size and shape, dark and firm on section.

Weight of spleen 3 oz. (85 grammes), small but healthy on section.

Right kidney weighed 5 oz. (141 grammes), left 8 oz. (226 grammes); capsule peeled cleanly, substance dark and firm, cortex of normal depth.

Suprarenal capsules, stomach and pancreas healthy.

Small intestine œdematous, but otherwise normal.

The last foot of the large intestine was gravely diseased; the wall, including mucosa, submucosa, muscle and serosa, was markedly thickened. The mucous membrane was coated with a thick gray slough or pellicle, and in places this was eroded and the submucosa laid bare; there was no deep ulceration, and the rest of the large intestine was normal. The contents of the large bowel were fluid and of light yellow colour.

The glands into which the lymphatics from the rectum and sigmoid flexure empty were red and enlarged.

Bladder normal. Prostate normal. Left testicle fibrotic.

Microscopic Examination.

The following parts were submitted to examination: (*a*) a series of posterior root ganglia with attached roots and peripheral spinal nerves; (*b*) the spinal cord.

(*a*) *Posterior Root Ganglia.*

The posterior root ganglia examined were the 6th, 7th, 8th, 9th and 10th dorsal of both sides.

The method employed was as follows: All were primarily fixed in formalin 5 per cent. and afterwards hardened in alcohol. Corresponding pairs from opposite sides were then embedded in celloidin in juxtaposition, special means being employed for the identification of the right ganglion. The pairs of ganglia were then cut transversely, in strict series, no sections being thrown away.

The sections of the 6th and 7th ganglia were stained in Ehrlich's acid hæmatoxylin, those of the 8th, 9th and 10th

ganglia by the hæmatoxylin fuchsin method of van Gieson, modified as follows: instead of Delafield's hæmatoxylin Ehrlich's acid solution was employed, and both after staining with hæmatoxylin and after the treatment with the picric acid and fuchsin solution, the sections were washed in dilute lithia water instead of plain water. This was found of advantage in so much as it intensified the blue or purple tints, prevented overstaining with fuchsin, and also accelerated the process.

Dorsal 8. *Left.*—Beginning at the central end of the series, the spinal nerve-roots show grave alteration. The change is bilateral, and does not affect the actual bundles of nerve-fibres so much as their investments. The sheath of pia mater, which is reflected on to them from the spinal cord, presents a general inflammatory thickening and is densely infiltrated with small round cells (in places there are large collections of these bodies), and in many instances the inflammatory exudation has penetrated the perineurium of individual nerve-bundles and given rise to changes in them. Thus the anterior and posterior roots have the appearance of being glued together by an inflammatory material. Wherever blood-vessels are present they are congested, and in some instances they are surrounded by hæmorrhagic extravasations. The next twenty sections show no noteworthy change, but thirty to forty sections from about the centre of the ganglion exhibit an alteration of the sheath which must be regarded as pathological. Running round about one-sixth part of the circumference of the sheath, and lying mainly on and without it but partly within its lamellæ, is a dense layer or collection of small round cells, about as deep as the sheath itself. The portion of sheath affected lies not far removed from the motor root. We are forced to look upon this alteration as pathological, because such a change is not to be seen in the corresponding ganglion of the opposite side, nor in any other of the ganglia from this case which we examined. But at the same time it is not quite like the ganglionic lesion which we have discovered in other cases of herpes; for the nerve-cells which lie immediately subjacent to the portion of thickened sheath are apparently left intact, at any rate they are certainly not destroyed *en masse*, as they generally are, and though their nutrition may have been interfered with, the only positive evidence thereof is the presence among them of a few foci of small round-cell proliferation in the neighbourhood of the blood-vessels.

The remaining sections of this ganglion show no change.

Dorsal 8. *Right.*—This ganglion differs markedly from the 8th dorsal ganglion of the opposite side. For although there is a similar perineural inflammation around the posterior root, all signs of inflammation cease some distance before the ganglion is reached. Moreover, the sheath of the right ganglion shows no signs of thickening, and there is no inflammatory focus corresponding to that in the ganglion of the left side. The cells of the right ganglion are, as far as can be seen by the modified

van Gieson method employed, quite normal in number and distribution.

Dorsal 7. *Right and left ganglia.*—The inflammatory change round the nerve-roots noticed in dorsal 8 is almost absent, and the sheath and substance of these ganglia are normal.

Dorsal 6, 9 *and* 10. *Right and left ganglia.*—Sheath and substance of the ganglion show no abnormal change.

Spinal Cord.

Stained by Marchi's method, and transverse sections cut at the level of entry of the 10th, 9th, 8th, 7th, 6th, 5th and 1st dorsal, and 7th cervical nerve-roots. (Plate 12, fig. 3.)

Entry of dorsal 8.—A few definitely degenerated fibres enter the cord at this level from the left posterior root. They appear as lines of black masses just internal to the tip of the posterior cornu, and in sections through the upper part of the segment; the same fibres are seen a little further in cut transversely. This degeneration is to be referred to the lesion in the left 8th dorsal ganglion.

In addition to this acute degeneration, there are two strips of partial tabetic sclerosis symmetrically disposed in the posterior column, one of which is situated along the line of junction of the columns of Goll and Burdach, and the other borders the posterior median septum. These areas are only partially sclerosed, for some healthy fibres can be seen throughout them. In the lateral pyramidal tracts of both sides, and also in the direct pyramidal tracts, disseminated, acutely degenerated fibres of large calibre are to be seen, the right anterior and the left lateral tracts being especially affected. This degeneration is referable to the general paralysis from which the patient suffered.

Dorsal 7.—No acutely degenerated fibres enter at this level, and those seen in the last section lie as a strip adjacent to, but not quite touching, the outer one-third of the posterior cornu. The diseased fibres are of medium calibre and their total number does not exceed seventy.

The pyramidal degeneration and the tabetic sclerosis above-mentioned are still present, but as they can have no connection with the herpes no further reference will be made to them.

Dorsal 6.—The degenerated fibres in the left postero-external column are slightly further removed from the cornu, and the dorsal extremity of the strip approaches the periphery.

Dorsal 5.—The number of acutely diseased fibres is sensibly diminishing.

Dorsal 1.—An extremely delicate, but, at the same time, distinct strip of degenerated fibres is visible in the left posterior columns running from the periphery downwards in the direction of the posterior commissure, along the line of junction of the columns of Goll and Burdach. The same strip is not recognisable in the right posterior columns.

Cervical 7.—The degenerated strip seen in the left posterior columns at dorsal 1 is still just discernible; it has now gained the postero-internal column.

Thus the microscopic changes found in this case may be summed up as follows:—

All the posterior root ganglia were healthy, excepting the 8th dorsal of the left side, which showed a local thickening of the sheath at about its centre. The proximal extremity of the ganglion was also involved in an inflammatory lesion which had caused destruction of some few ganglion cells.

Of the posterior roots examined several, viz., the 6th, 8th, 9th and 10th of both sides, were affected by a tabetic inflammatory process, and in the posterior columns of the cord also were signs of early tabes.

A number of acutely degenerated fibres entered the spinal cord by the 8th dorsal posterior root of the left side, forming a field of degeneration that followed the usual course.

At first sight it would appear that this case was vitiated by the co-existence of the tabetic process; but in reality it was thereby rendered more instructive. We know that it is uncommon in an ordinary case of tabes dorsalis to find prominent inflammatory changes in the posterior root ganglia. But at the same time the occurrence of herpes in cases of tabes dorsalis is a recognised clinical fact, and it is probable that in such cases the inflammatory process in the posterior roots peculiar to tabes spreads to the posterior root ganglion and so determines the herpetic eruption. We believe that the above case is an illustration of this condition.

That the 8th dorsal ganglion of the left side would, in this instance, be only slightly diseased, was to be expected from the mild and scattered form assumed by the eruption; but the fact that it was the only ganglion diseased, coupled with the typical acute spinal degeneration entering at the 8th root, renders the case confirmatory from the point of view of localisation.

Case 18.—Percy Matthew T., aged 31. Admitted to Rainhill Asylum, October 15, 1896. Died October 12, 1897.

SUMMARY.

Admitted to Rainhill Asylum suffering from general paralysis of the insane. Speech slurred. Knee-jerks exaggerated. Pupils react sluggishly to light. Tongue tremulous.

On September 12, 1897, *a herpetic eruption appeared which involved the skin of the chin and cheek of the right side of the face (inframaxillary division of 5th nerve) (fig.* 18). *Death occurred from general paralysis on October* 12, 1897, *thirty days after the appearance of the eruption.*

Microscopic Examination:—

(*a*) *Gasserian ganglia.—In that portion of the right ganglion which receives the fibres of the inframaxillary division of the nerve, is an evident focal lesion destroying nerve-cells and nerve-fibres, over an area measuring* 1·275 *mm. by* ·765 *mm.*

(*b*) *Roots of* 5*th nerves central to ganglia.—In that segment of the right root in which we suppose the fibres that belong to the inframaxillary branch are distributed, scattered degenerated fibres are visible, and also three small fasciculi which are gravely affected, partly by a sclerotic process and partly by acute degeneration.*

(*c*) *Inframaxillary divisions of* 5*th nerves.—Scattered degenerated fibres are seen all over the section and also small sclerosed areas.*

(*d*) *Pons and medulla.—Definite acute degeneration of certain fibres of the sensory root of the* 5*th nerve of the right side, which can be traced down to the base of the substantia gelatinosa Rolandi, at the level of the* 1*st cervical anterior root.*

FIG. 18.

To show the distribution of the eruption in Case 18.

History.—There was insanity in his family. He was infected with syphilis at the age of 24, and for this he received no medical treatment other than that afforded by quacks. In May, 1895, he became melancholic after an attack of influenza, and was confined for two months in Cheadle Asylum.

State on admission.—Poorly nourished. Speech slurred and indistinct. Gait rather feeble and springy. Some facial tremor. Knee-jerks very brisk, equal; superficial reflexes present. Pupils of moderate size, hardly reacting at all to light; margins circular. Tongue protruded straight, but tremulous. Circulatory, respiratory, and alimentary systems normal. Urine: specific gravity 1020, no sugar or albumen. Mentally restless, excited, incoherent; memory defective.

Progress.—He gradually deteriorated mentally and physically, and eventually reached a condition of almost complete dementia; during his latter days he had several typical "general paralytic" seizures.

September 12, 1897.—A discrete crop of herpetic vesicles appeared on the chin and lower part of the cheek of the right side of the face; a few vesicles were also seen on the scalp a couple of inches above the ear on the same side. The skin intervening between these vesicles and also all the way up the lateral aspect of the cheek was markedly erythematous. The area affected corresponded to the cutaneous distribution of sensory fibres of the inframaxillary division of the 5th nerve.

September 21.—The vesicles had not increased in number, and those previously noted were now pustular. The erythema had persisted.

September 28.—The erythema was disappearing, and the vesicles were scabbing.

October 6.—Some seven or eight small scabbed patches were visible on the chin and three or four more similar patches on the scalp, a couple of inches above the ear. In the latter position there was also one pustule of considerable size.

October 12.—Death from "general paralytic" exhaustion thirty days after the first appearance of the herpetic eruption.

Post-mortem Examination.

Post-mortem examination thirty-four hours after death. Weather cold.

Body emaciated. Poor muscular and skeletal development. No localised muscle atrophy or contracture. Herpetic scabbing on chin and above ear on right side; skin otherwise healthy.

Calvaria normal.

Dura mater slack anteriorly; no abnormal thickening or unusual adhesions to bone or arachnoid. Dural sinuses partly filled with *post-mortem* clot. A moderate excess of clear, watery, sub-dural fluid; no free blood.

Pia-arachnoid markedly thickened and opaque universally; its removal caused patchy decortication.

Main arteries and veins healthy to the naked eye.

Cerebral hemispheres of fair size, equal; segments proportionally developed. Arrangement of convolutions simple; signs of general atrophy most marked frontally; sulci rather wide.

Cortex dark, fairly firm, hyperæmic, reduced in depth, with indistinct striation.

White matter appeared healthy.

Ventricles increased in size, contained an excess of fluid; ependyma faintly granular. Choroid plexuses congested.

Basal nuclei and other cerebral structures macroscopically normal.

Cerebellar cortex dark and thin.

Pons and medulla of normal size and shape, consistence fairly firm all through; gray substance generally hyperæmic; floor of 4th ventricle granular.

The pituitary body, cranial nerves, and Gasserian ganglia present no naked-eye alteration of any description.

An examination of the spinal cord was prohibited, but the three upper cervical segments were extracted through the foramen magnum.

Some old fibrous adhesions existed round the apices of both lungs. On section of the lungs general congestion and œdema was noticeable, and scattered throughout the lower lobes were firm patches of lobular pneumonia.

Heart small, muscle dark and firm; no valvular disease.

Aorta and large blood-vessels healthy.

Peritoneum normal.

Liver dark and firm. Gall bladder healthy.

Spleen normal. Kidneys dark and firm; capsule stripping cleanly.

Suprarenal glands, stomach, pancreas, small and large intestines, bladder, prostate gland, vesiculæ seminales and testes free from morbid change. No obvious syphilitic scarring could be found on the penis.

Microscopic Examination.

A microscopic examination was made—(*a*) of both Gasserian ganglia, (*b*) both 5th nerve-roots in their extrapontine course, (*c*) both inframaxillary nerves, (*d*) the crus cerebri, pons varolii, and medulla oblongata.

(*a*) *Gasserian Ganglia.*

Method of examination.—The ganglia were primarily hardened in a mixture of equal parts of formalin 4 per cent. and Müller's fluid, afterwards in absolute alcohol, embedded side by side in celloidin, and cut transversely together on one and the same block. In this manner in every section we obtained a view of both ganglia, and we were enabled with ease and convenience to compare the healthy and affected sides. The sections were kept in strict serial order, and every alternate one was stained by the old copper-hæmatoxylin method of Weigert and mounted. In all 110 sections were examined (plate 9.)

In the first sections, along the dorsal margin of the right ganglion, at about the junction of the outer with the middle 3rd, situated immediately below the dura and almost opposite the motor root, are three small nerve-bundles which are obviously diseased; the principal change in them must be described as a sort of sclerosis, that is to say, they stain very much more palely than adjoining bundles, are to a large extent deprived of nerve-fibres, and some of those fibres which remain appear to be swollen; furthermore, these bundles contain an excess of connective tissue.

These three bundles can be readily followed along section by

section, gradually assuming a more external position, until in the thirty-first section they split up to form five smaller fasciculi.

The corresponding nerve-bundles in the left ganglion are free from obvious change, and so likewise are all the other nerve-bundles motor and sensory, all the ganglionic substance, and the pia-arachnoid and dura cut in the first thirty-eight sections.

At about the thirty-ninth section signs of thickening and excessive development of the pia-arachnoid overlying the above-mentioned sclerosed bundles of the right side becomes evident. In the succeeding sections the bundles approach, and in the forty-sixth section join, a portion of ganglion pertaining to the inframaxillary division of the nerve. This portion of the ganglion is infiltrated by numbers of small round cells, and in the forty-ninth section it becomes converted into a definite focal lesion, which gradually increases in dimensions to attain its maximum size at about the fifty-third section; it then tails off again and disappears in the fifty-eight section.

Described in detail where it is best developed the lesion has the following character:—It is situated in a tongue-shaped portion of the ganglion on the dorsal aspect, immediately beneath the dura mater, at the junction of the middle with the outer one-third of the ganglion; directly opposite to it, on the ventral surface, lies the motor root of the 5th nerve. In form, on transverse section, the focus is roughly oval, its greatest transverse diameter being 1·275 mm., its greatest vertical ·765 mm. Structurally it is made up of a large central nucleus, which is tinted brown, but is for the greater part of indefinite composition. In it can be seen some scattered small round cells, a few engorged blood-vessels, and interspersed here and there what appear to be the remnants of nerve-cells. Encircling the central position is a thin purple-stained zone in which small round cells are abundantly congregated. Enveloping this zone, extending up to the pia on the free surface and for some distance into the surrounding ganglionic substance, is a wider zone, which is extremely densely infiltrated with small round cells and in which remains only of nerve-cells and nerve-fibres can be seen along with congested blood-vessels. Outside this zone the nerve-cells and fibres of the ganglion soon assume a healthy aspect. The pia covering the mass is thickened and infiltrated with small round cells. The inner surface of the over-lying dura is also slightly affected in a similar manner. The remainder of the ganglionic substance and the other bundles of nerve-fibres of this ganglion are healthy.

Sections fifty-nine to sixty-five show a gradual diminution in the over-cellularity of the ganglionic tissues before occupied by the focus, and there now appears, on the outer side of this area, a fasciculus of nerve-fibres of considerable size, of which about one-third in sectional area is sclerosed. This bundle can be followed into the peripheral trunk of the inframaxillary division and disappears from view at about the seventy-fifth section.

The remaining sections exhibit no change of importance.

The left Gasserian ganglion is free from any signs of disease

(*b*) *Roots of 5th Nerves Central to Ganglia.*

Method of examination.—Both roots (right and left) were stained by the method of Marchi, fixed together in juxtaposition in one block in celloidin and cut serially in the transverse direction; every alternate section of the series was mounted.

Commencing with the sections of the more peripheral portions of the root, the right can always be distinguished from the left by the existence of degeneration in it. This degeneration is not of a striking character, but it is, nevertheless, just what one would expect when one takes into consideration the comparatively slight extent of the herpetic eruption. It is principally confined to three small fasciculi lying at the periphery of the section, opposite to the motor root, which root can always be identified in being uniformly composed of fibres of large calibre, whereas the sensory bundles contain fibres of mixed calibre, large and small. The change which these three bundles present is chiefly of a sclerotic character and is suggestive of an acute parenchymatous degeneration some weeks old, of which the blackened fatty masses have been to a great extent absorbed; thus the ground of the affected fields is white in colour and scattered over it are round or irregular-shaped black masses and an appreciable number of empty, swollen, primitive sheaths. In this way about three-fourths of one bundle is affected, about one-half the next and about one-third of the next. Taken altogether it cannot be said that more than one-twentieth part of the sensory root is so involved.

In addition to the sclerotic affection of these three bundles, all the other bundles in that segment of the root which one regards as being composed of inframaxillary branches show blackened degenerated fibres disseminated throughout them.

The other bundles, which are probably derived from the 1st and 2nd branches of the nerve, and also the motor root, are quite free from disease.

The root of the left side is absolutely healthy and shows nothing resembling that on the right side.

The changes in the right root above noted can be plainly traced centrally on to the point of entry of the root into the side of the pons varolii.

Peripherally they evidently correspond with the three fasciculi noted as being sclerosed in the early sections of the right ganglion.

(*c*) *Peripheral Nerve-trunk of Inframaxillary division.*

The sclerotic condition of a bundle of nerve-fibres leading away from the focal lesion in the right ganglion into the nerve-trunk has already been alluded to. Sections of this trunk a short distance peripheral to the ganglion, stained by the method of Marchi, show a considerable number of acutely degenerated fibres scattered fairly evenly over the various bundles comprising the trunk, and

likewise a partial sclerosis of some bundles. The perineurium is unchanged.

The facial branches of the nerve could not be examined.

(d) Pons Varolii, Crus Cerebri and Medulla Oblongata.

Method of examination.—To study the condition of the 5th roots in their intrapontine and intramedullary course, the crus cerebri, pons and medulla were cut up transversely into thin slices and stained by the method of Marchi.

In the first place the motor, so-called descending or cerebral root, is quite free from degeneration from its point of issue from the pons to as far up in the crus cerebri as it is possible to trace it.

It might also be mentioned here that in the sections above the level of entry of the 5th roots, the various systems of nerve-fibres, viz., the superior cerebellar peduncles, the lemnisci, the posterior longitudinal bundles, the fibres of the tegmentum, the transverse pontine fibres, &c., show no degeneration whatever, but in the motor or pyramidal tracts of either side disseminated acutely degenerated fibres may be recognised. This degeneration is, no doubt, part of the "general paralysis," and is unconnected with the herpetic lesion.

The sensory, so-called ascending or spinal root of the right side shows marked degenerative changes in its entire course. Described in detail these are as follows (plate 13):—

(*a*) Sections which catch the right trigeminal root just at its point of entry into the pons show disseminated degenerated fibres in all the bundles of the sensory root, but in the outer portion of the root two or three fasciculi are observed which are gravely affected and contain numerous rows of blackened fatty masses, indicating acute degeneration. These are probably the same bundles as were described as being partially acutely degenerated and partially sclerosed in transverse sections of the root between the pons and the ganglion.

(*b*) Sections slightly more caudalwards show similar degeneration in the intrapontine part of the sensory root, obliquely cut as it courses upwards and inwards in the direction of the trigeminal nucleus.

(*c*) The next sections show strands of degenerated fibres quite close up to the sensory trigeminal nucleus, and also among the cells of the nucleus a few degenerated fibres of small calibre can be seen running. The method is not adapted for the display of changes in the nerve-cells themselves. The motor nucleus is clearly visible and there is no fibre degeneration in it.

Without serial transverse or longitudinal sections it is impossible to see the exact relation of the degenerate sensory fibres to the sensory nucleus, but the majority of the fibres, at any rate, do not seem to come into connection with the nucleus, but appear to curve abruptly downwards and ventral to it.

(*d*) In sections slightly below the level of the 5th nucleus the sensory root is seen forming up into a pear-shaped area with the thin end upwards. Scattered over the upper two-thirds of this area many degenerated fibres are seen, some cut transversely but the majority obliquely. In the lower one-third a few diseased fibres only are to be found.

No degenerated fibres are anywhere seen running beneath the floor of the 4th ventricle to cross to the opposite side.

(*e*) Sections opposite the 6th nuclei are similar to the last.

(*f*) In sections opposite the 7th and 8th roots the degenerated fibres in the right sensory root are all cut more or less transversely; they are scarce in the lower one-third of the field, moderately numerous in the upper third and most numerous at about its middle.

The roots of the 7th and 8th nerves are intact.

(*g*) Sections opposite the 9th and 10th roots show similar degeneration.

(*h*) Opposite the great olive, where the root approaches the surface, it is to be noted that the degenerated fibres are not so numerous as they were above, and it is again to be observed that the lower one-third of the field contains few diseased fibres.

(*i*) Opposite the main decussation of the fillet degenerated fibres are seen scattered throughout that part of the 5th root which lies between the dorsal half of the substantia gelatinosa Rolandi and the surface adjoining the funiculus cuneatus, and degenerated fibres are seen running in the most dorsal part of the substantia gelatinosa. In the more ventrally situated part of the same field degenerated fibres are scarce.

(*j*) Opposite the upper part of the pyramidal decussation, the distribution of degenerated fibres in the right 5th root is similar, but they are becoming markedly scarcer. Other degenerated fibres are seen in the innermost dorsal part of the base of the substantia gelatinosa, not far removed from the glosso-pharyngeal root.

(*k*) Opposite the remainder of the pyramidal decussation and opposite the 1st cervical root the degeneration is indistinct, but at the base of the substantia gelatinosa, in its most dorsal part, is an obvious collection of small black dots, which is not represented on the opposite side.

Below this level degeneration cannot be definitely traced.

There remains to be mentioned that in all the above sections scattered degenerated fibres of large calibre were found throughout the pyramidal tracts of both sides; as already stated, this degeneration is to be associated with the general paralysis which caused the patient's death.

Likewise in the posterior longitudinal bundles and lemnisci of both sides are a few degenerated fibres (about half a dozen). These may be attributed to the same cause as the pyramidal degeneration.

The sensory root of the 5th nerve of the left side examined

throughout shows nothing at all resembling the condition seen in the right root.

No other cranial nerves issuing from or entering the pons or medulla show degeneration.

Case 19.—William C., aged 43 (Rainhill Asylum). Admitted September 25, 1895. Died May 8, 1896.

SUMMARY.

On November 1, 1895, *an herpetic eruption appeared on the forehead immediately above the right eyebrow* (*fig.* 19). *Death from general paralysis, May* 8, 1896, 190 *days after the appearance of the eruption.*

Microscopic Examination :—

There seems to be a focus of disease in the ganglionic substance pertaining to the ophthalmic division of the right 5th nerve, but as there was a fault in the method of examination we prefer to withhold any definite statement concerning this lesion.

In the root of the right 5th nerve central to the ganglion and in that part of the root which we take to be a portion of the ophthalmic division, several small nerve-bundles are seen which are partially sclerosed, but in the roots of the nerves within the pons and medulla no difference between the two sides can be appreciated.

There is no noteworthy alteration in the ophthalmic division of the nerve peripheral to the ganglion.

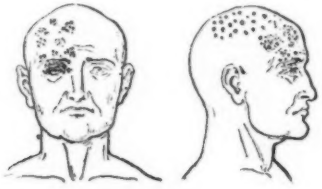

FIG. 19.

To show the distribution of the eruption in Case 19.

History.—He was married and had had one child only, which was still-born. Syphilis was not denied. He was an egg merchant, and drink and failure in business were assigned as the causes of his insanity.

On admission.—He was a weak and feeble general paralytic. Speech blurred and indistinct. He could walk, but was distinctly ataxic. Muscular and well nourished. No actual paralysis.

Knee-jerks absent. Pupils equal and did not react to light. No paralysis of the face. Tongue tremulous and somewhat wasted. Circulatory and respiratory systems normal. Urine normal when collected by catheter.

Mentally he had grandiose delusions, was restless and resistive, and wet and dirty in his habits.

November 1, 1895.—He developed herpes of the forehead, which reached its full development two days later (fig. 19). The cornea remained unaffected throughout, and the disc and fundus were normal.

May 8, 1896.—He was seized with convulsions, from which he never recovered, dying 190 days after the first onset of the herpetic eruption.

Post-mortem Examination.

An examination of the head only was allowed; this was made seventeen hours after death.

State of nutrition fair. A large patch of skin on the front and to the left side of the chin was white and cicatricial, and here there was no growth of beard; this was the result of a burn. On the forehead, immediately above the right eyebrow, was a small and indistinct patch of herpetic pigmentation. Had it not been known that the patient had previously suffered from herpes in that position, this would probably have escaped observation.

Scalp and cranium normal.

Weight of encephalon 1,255 grammes. Dura mater relaxed anteriorly; no abnormal adhesions or thickening. Dural sinuses filled with black blood clot. Main arteries looked rather tough and white, but were not calcareous.

Cerebro-spinal fluid of clear watery character, markedly in excess. No subdural membrane or blood.

The arachnoid generally presented the blue milky opacity so commonly seen in general paralysis.

The pia mater was considerably thickened, difficult to remove, and hyperæmic; on stripping it decortication occurred in the frontal and parietal regions.

The cerebral hemispheres were equal in size, and the individual segments showed a normal development; but there were indications of general atrophy, most marked in the frontal region. The sulci were wide and shallow.

The right hemisphere unstripped weighed 540 grammes, the left 542.

Cortex dark, somewhat soft, hyperæmic, thin, and indistinctly striated.

No obvious change in white matter. General consistence rather soft.

The lateral ventricles were markedly dilated, and contained an excess of fluid. The ependyma over the basal nuclei was granular.

The basal nuclei were of dark colour and rather small.

The cerebellum weighed 127 grammes. Cortex dark and thin. General consistence rather soft. No lesions.

Pons and medulla together weighed 29 grammes. Gray substance dark in colour. Ependyma of 4th ventricle thick and granular.

Pituitary body and cranial nerve-roots presented no macroscopic morbid change.

The Gasserian ganglia and the portions of the three divisions of the 5th nerves, which were carefully extracted for detailed examination, showed no abnormality to the naked eye.

Microscopic Examination.

A microscopic examination was made of—(*a*) the Gasserian ganglia of both sides, (*b*) the 5th roots of both sides, (*c*) the ophthalmic divisions of the 5th nerves of both sides, (*d*) the crus, pons varolii, medulla oblongata, and the upper part of the spinal cord.

(*a*) *Gasserian Ganglia.*

Method of examination.—Each ganglion was divided transversely into two halves, and after staining by the method of Marchi, the distal portion was cut longitudinally and the central portion transversely.

It might here be noted that this was one of the earliest cases of herpes which we had the opportunity of submitting to microscopic examination; and experience has since taught us that the method of examination that we adopted was a faulty one. At that time our method aimed principally at the discovery of acute degeneration of nerve-fibres, and we were not alive to the importance of searching the ganglion mass closely for a local lesion, else the ganglion would not have been divided in the manner above described; for, as the description indicates, by so doing the lesion was probably obscured.

Right ganglion.—Taking first the transverse sections. These show a portion of the ganglionic substance pertaining to the ophthalmic division of the nerve along with the roots of the superior and inferior maxillary branches and the motor root. In none of these is there any acute degeneration, but on the ventral side of the section, not far to the left of the motor root and in close apposition to the ganglionic substance of the ophthalmic division of the nerve, there is one small bundle which presents an unhealthy appearance; it is deprived of a certain number of fibres, it contains indefinite débris, and its blood-vessels are dilated. Furthermore, in other sections this bundle can be seen making in the direction of the ganglionic substance of the ophthalmic division.

Examining next the longitudinal sections, it is seen that those portions of the ganglion pertaining to the superior and inferior

maxillary branches look healthy; but in several sections a portion of the ganglionic substance into which the ophthalmic branch runs has the appearance of being diseased. At one spot there seems to be the remains of a hæmorrhage, indicated by a collection of red blood corpuscles and a local destruction of nerve-cells; but unfortunately this portion lies just at the margin of the line of section by which the ganglion was divided into two halves, and it is therefore impossible to say certainly that this represents a hæmorrhage.

Left Gasserian ganglion.—The ganglion of the left side exhibits no change similar to that above described.

Fifth Nerve-roots.

Right.—Stained by the method of Marchi.

In the sections of the right root there are several small bundles which have a partially sclerosed aspect, but do not show acute degeneration; these are situated in that part of the root furthest removed from the motor root.

Left.—Normal.

Ophthalmic Branch of the 5th Nerve.

Stained by the method of Marchi.

From both right and left sides portions of the trunk before division, and portions of the frontal branch, showed no positive change.

Crus Cerebri, Pons Varolii, Medulla Oblongata, and Spinal Cord.

The crus, pons, and medulla were cut up transversely into thin slices and stained by the method of Marchi, and portions of the cervical cord were treated in the same way.

The sections of the crus and those of the pons above the level of entry of the 5th nerves show that the cerebral root of the 5th nerve is normal; there is likewise no degeneration in any of the other of the nerve tracts found at these levels, excepting the pyramidal tracts, and in these on either side acutely degenerated fibres of large calibre are disseminated. This degeneration is to be referred to the general paralysis from which the patient suffered, and it is visible not only here, but also in the sections from all the other levels examined.

In the sections which show the 5th roots immediately after their entry into the pons, the appearances are disappointing and no pronounced degeneration is visible on either side.

Similarly in the sections which display the course of the sensory root of the nerves, there is not sufficient change in the roots of the two sides to enable us to declare that the right is diseased and the left healthy.

A certain number of fibres in the roots of the 8th nerves of both sides show what we take to be true degeneration, but the

Fig. 1.

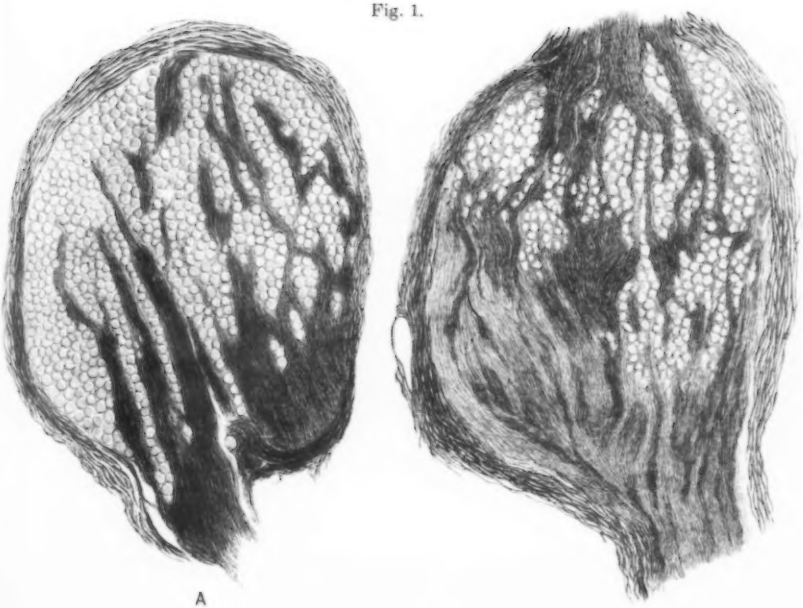

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Fig. 2.

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PLATE 2.

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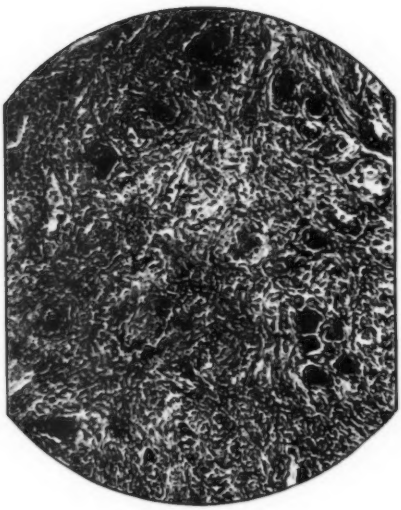

FIG. 2.

PLATE 3.

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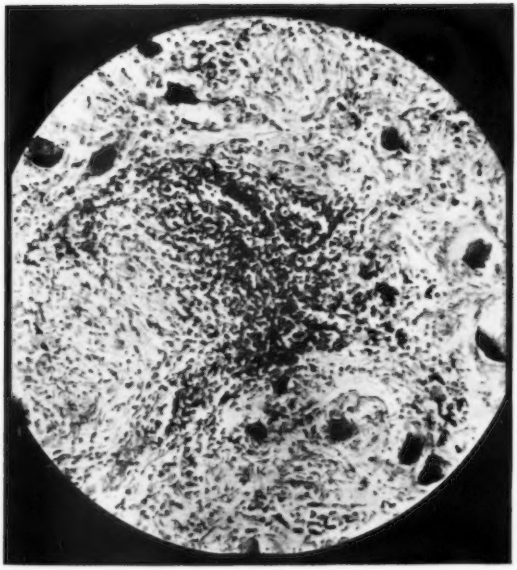
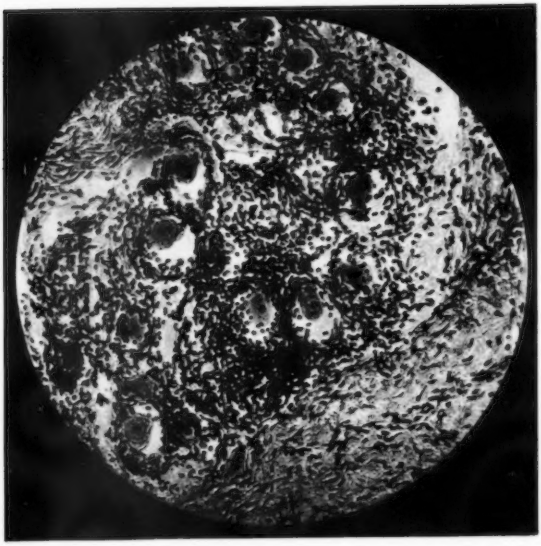


FIG. 2.

PLATE 4.



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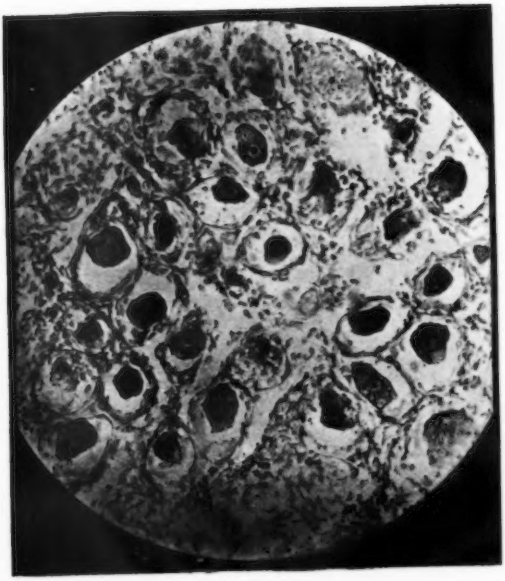

FIG. 2.

PLATE 5.

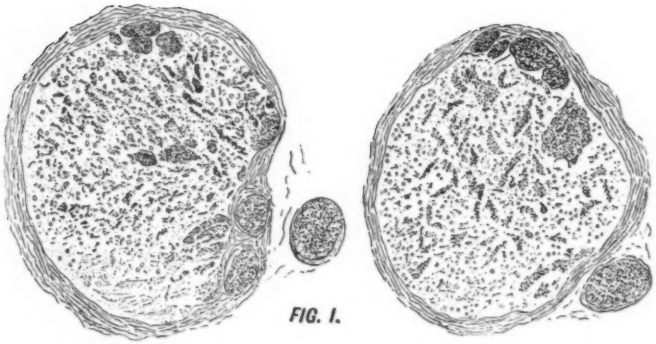

FIG. I.

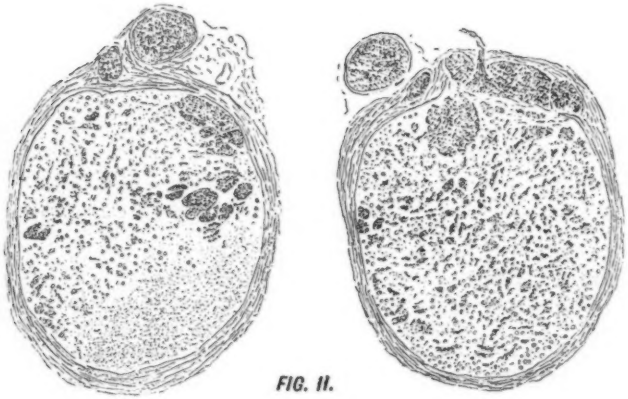

FIG. II.

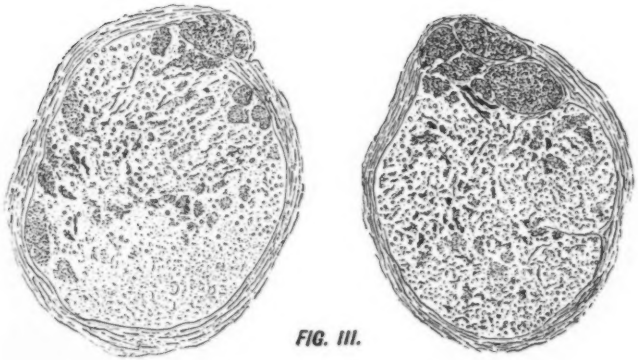

FIG. III.

PLATE 6.

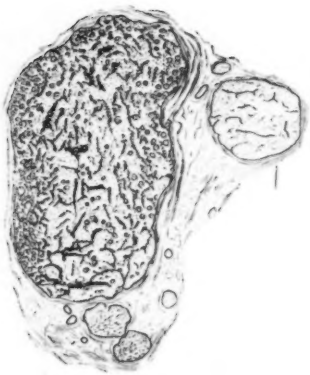

FIG. 1A.

FIG. 1B.

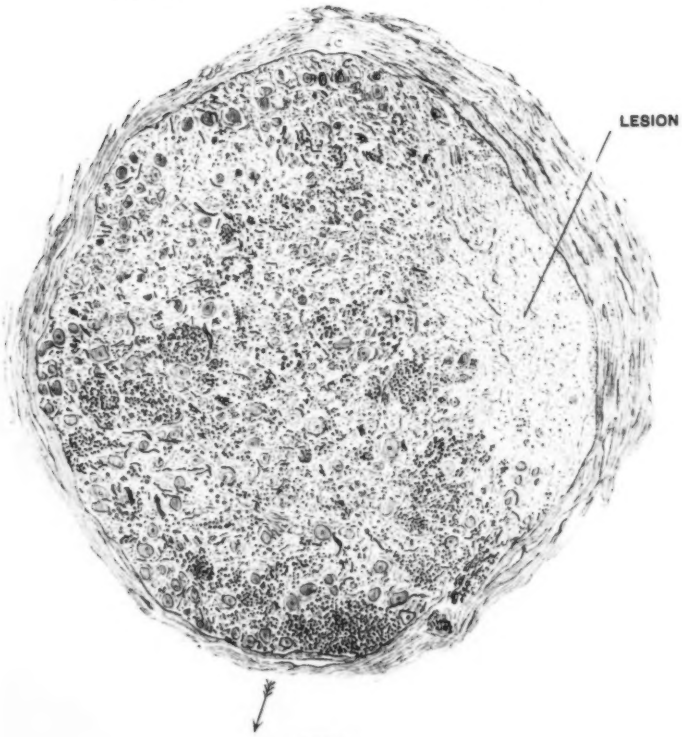

FIG. 2.

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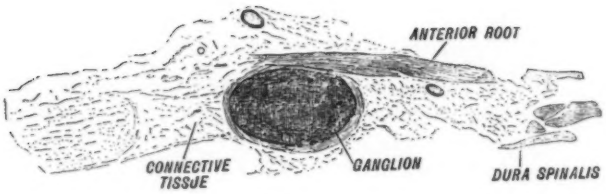


FIGURE I.

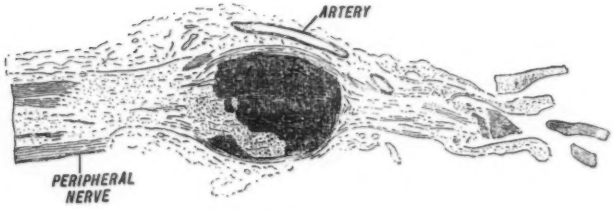
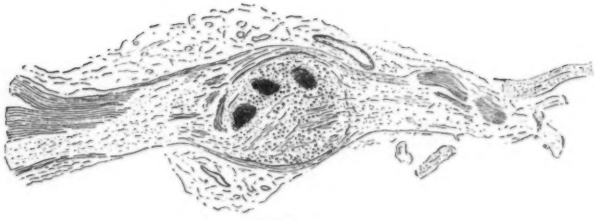


FIGURE II.



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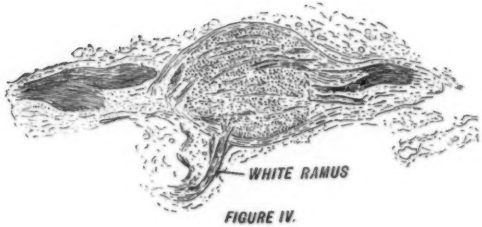
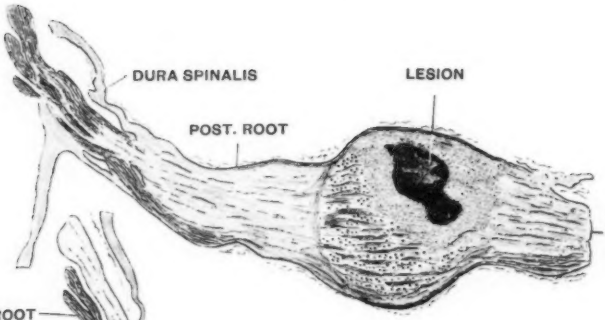


FIGURE IV.

PLATE 8.



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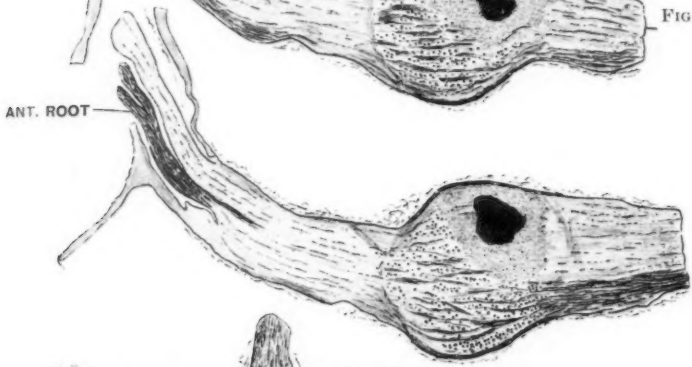

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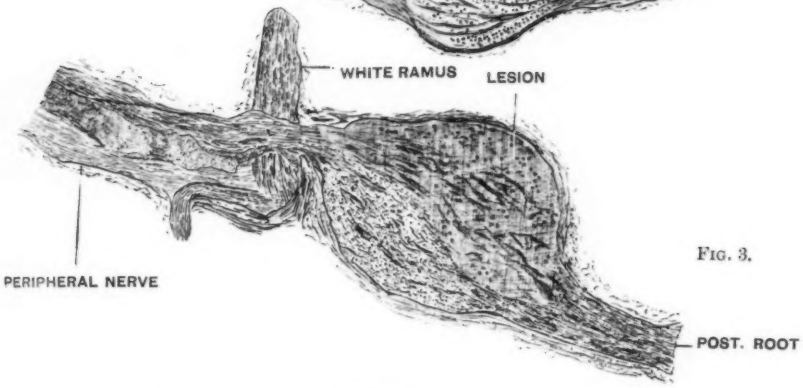

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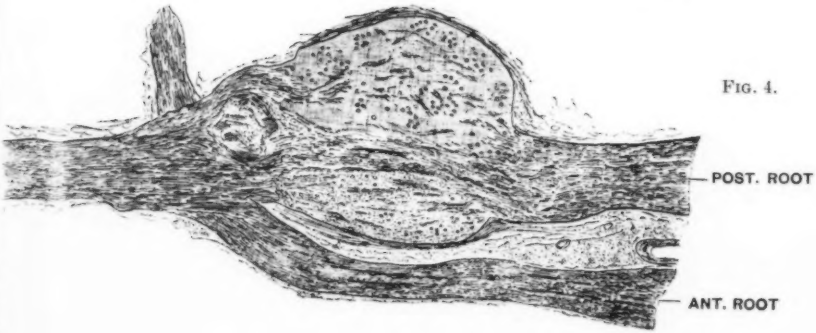

FIG. 4.

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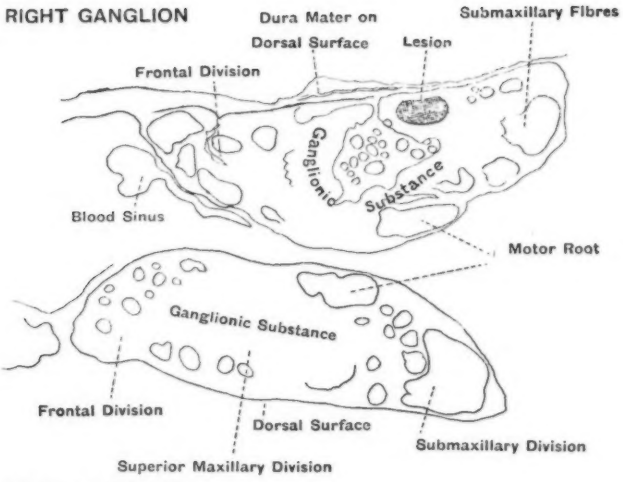


KEY TO PHOTO OF GASSERIAN GANGLIA.

PLATE 10.

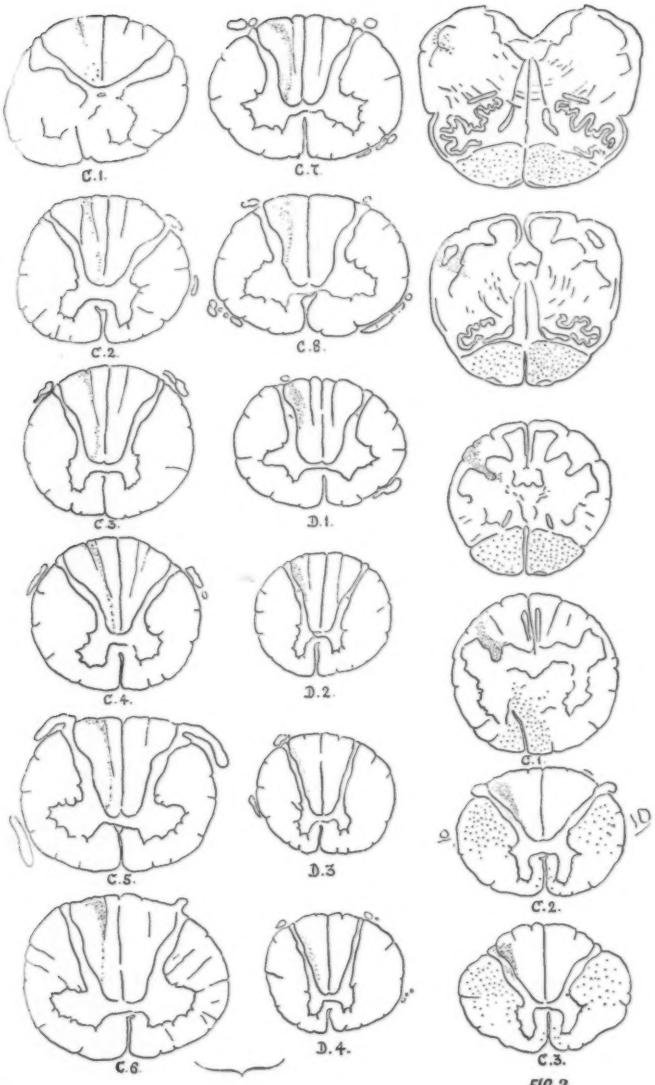


FIG. 1.

FIG. 2

PLATE 11

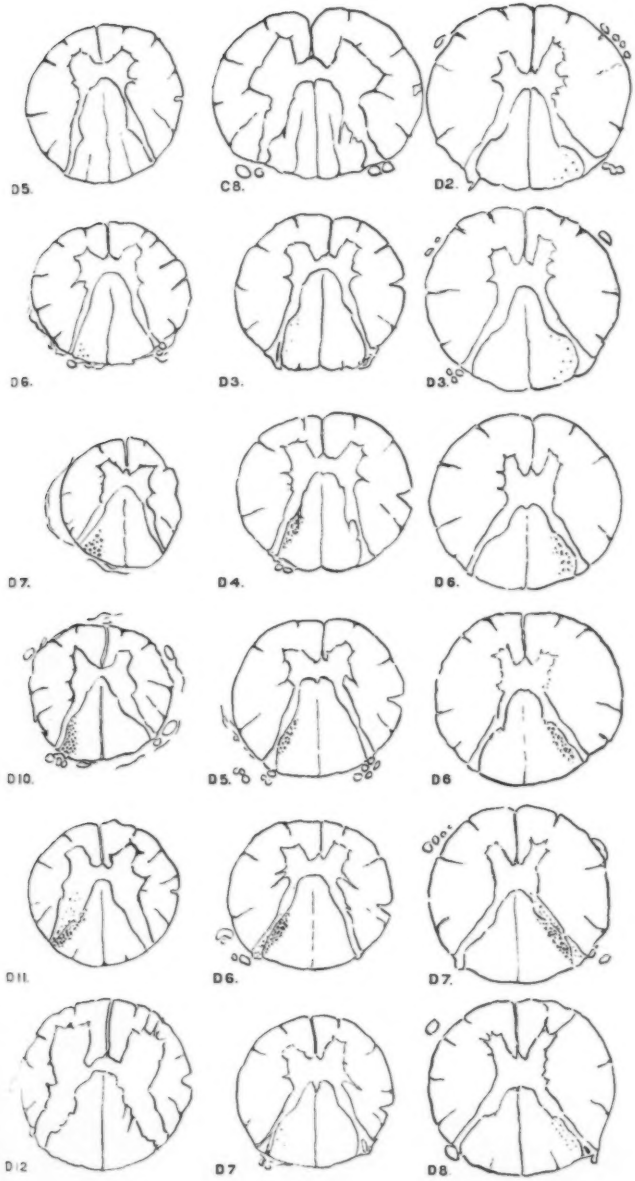


FIG. 1. FIG. 2. FIG. 3.

BRAIN 2 A

PLATE 12.

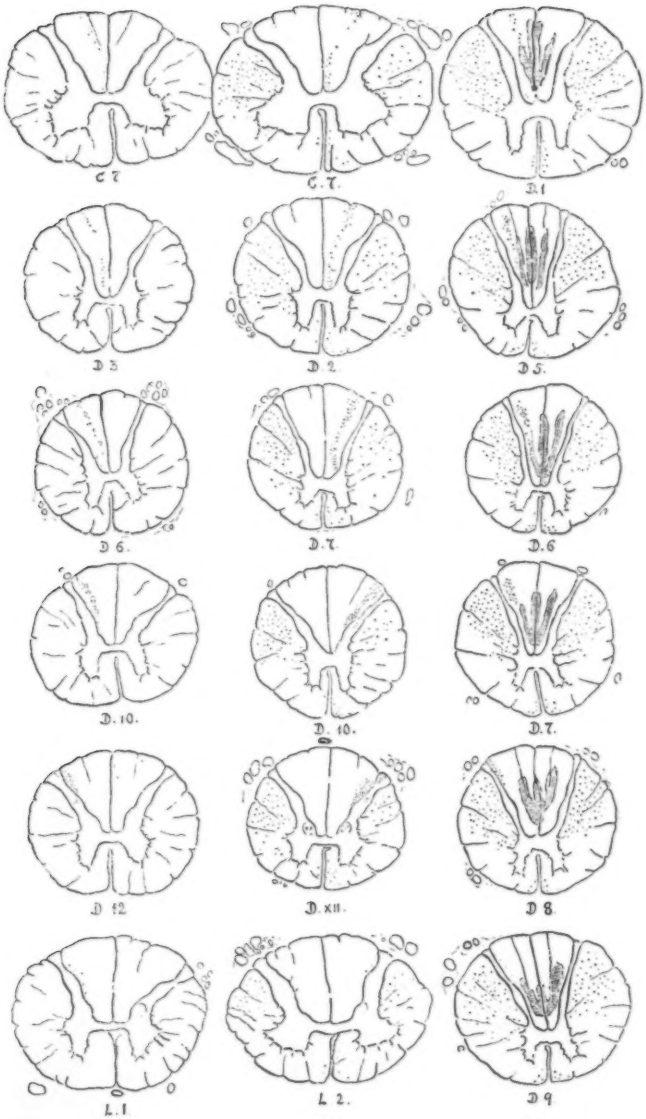


FIG. 1. FIG. 2. FIG. 3

PLATE 13.

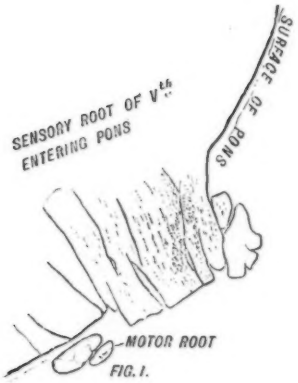
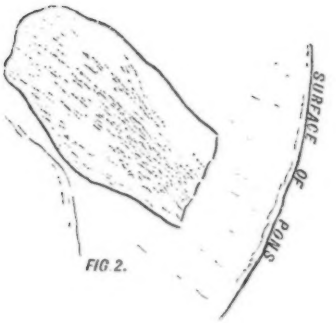


FIG. 1.



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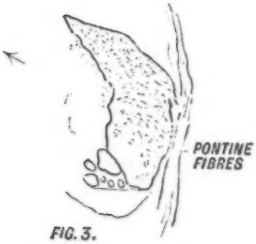

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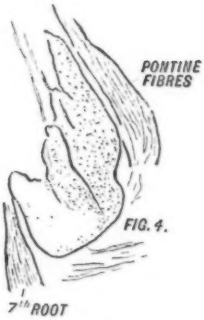

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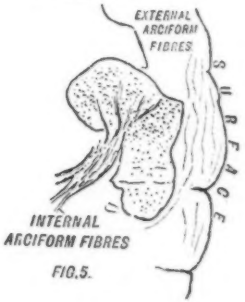

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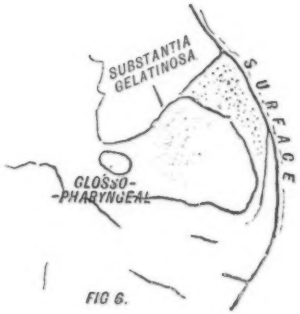


FIG 6.

PLATE 14.

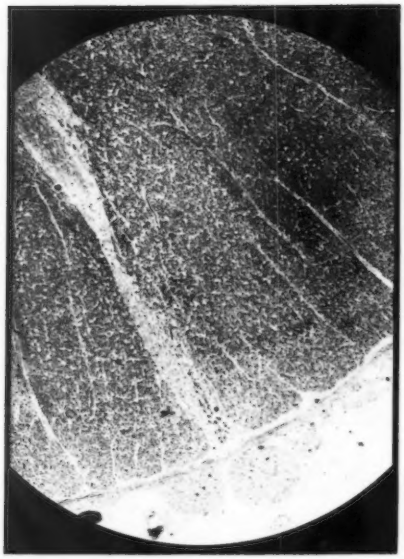


FIG. 1.

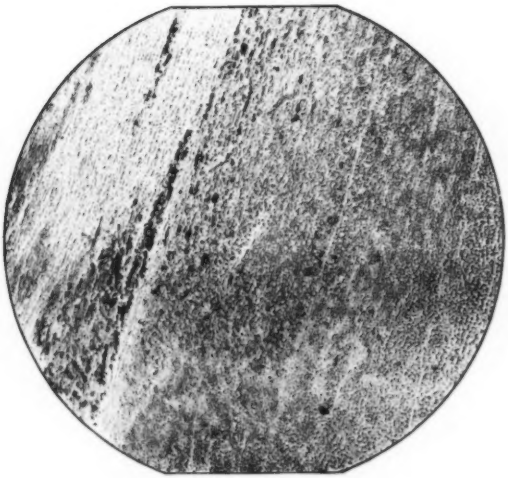
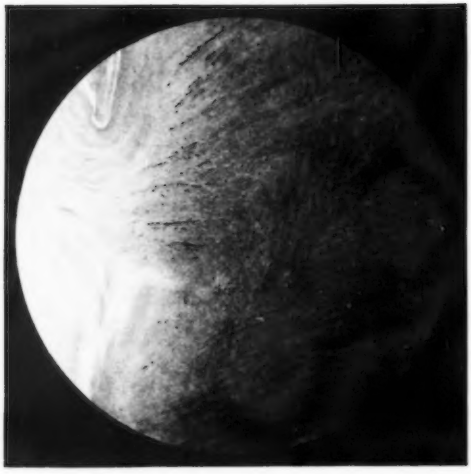


FIG. 2.

PLATE 15.



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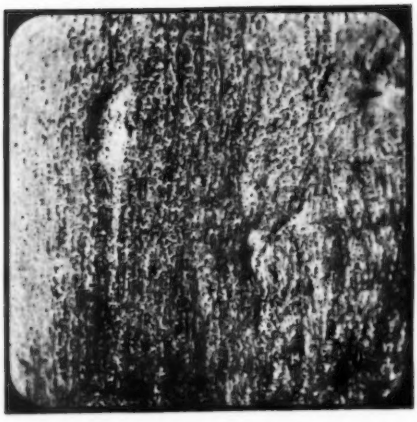


FIG 2.

PLATE 16.

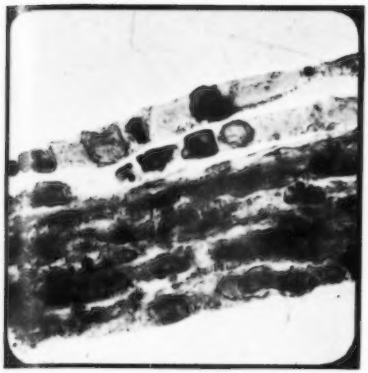
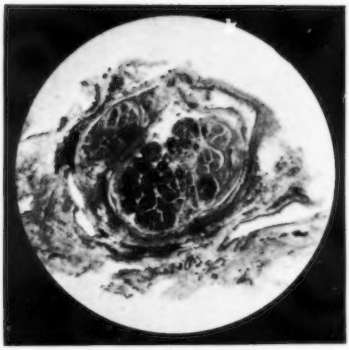


FIG. 1.



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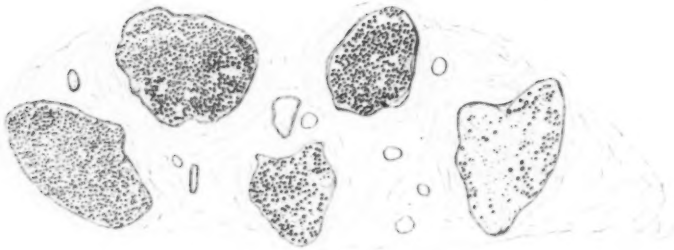

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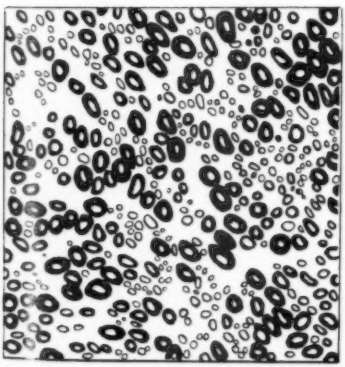

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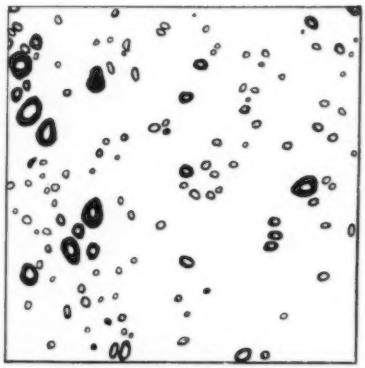


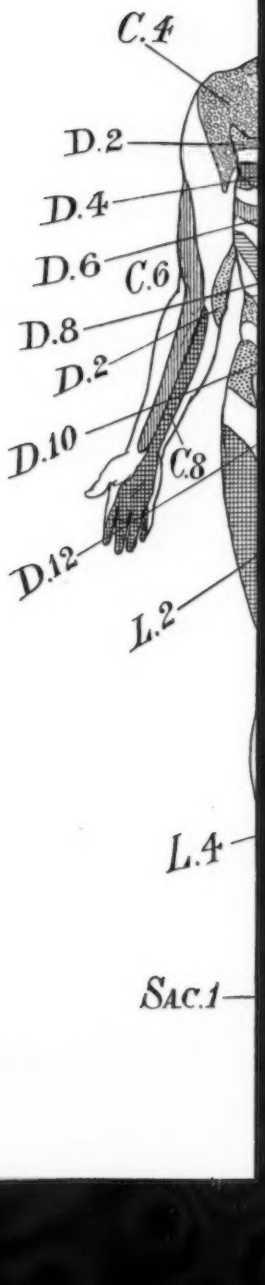
FIG. 5.

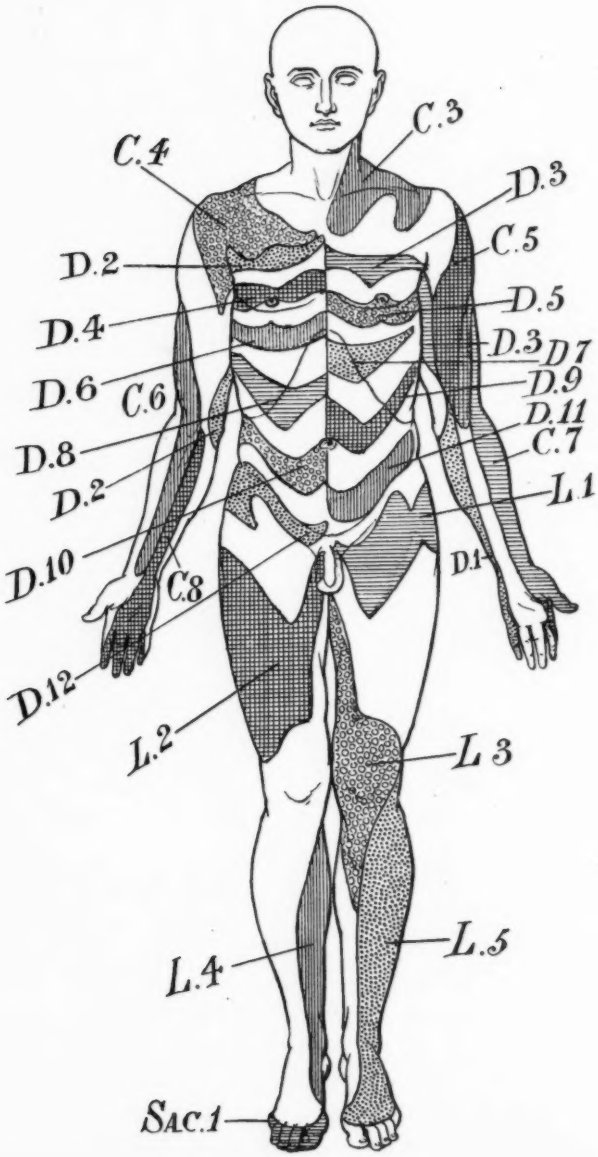
PLATE 17.

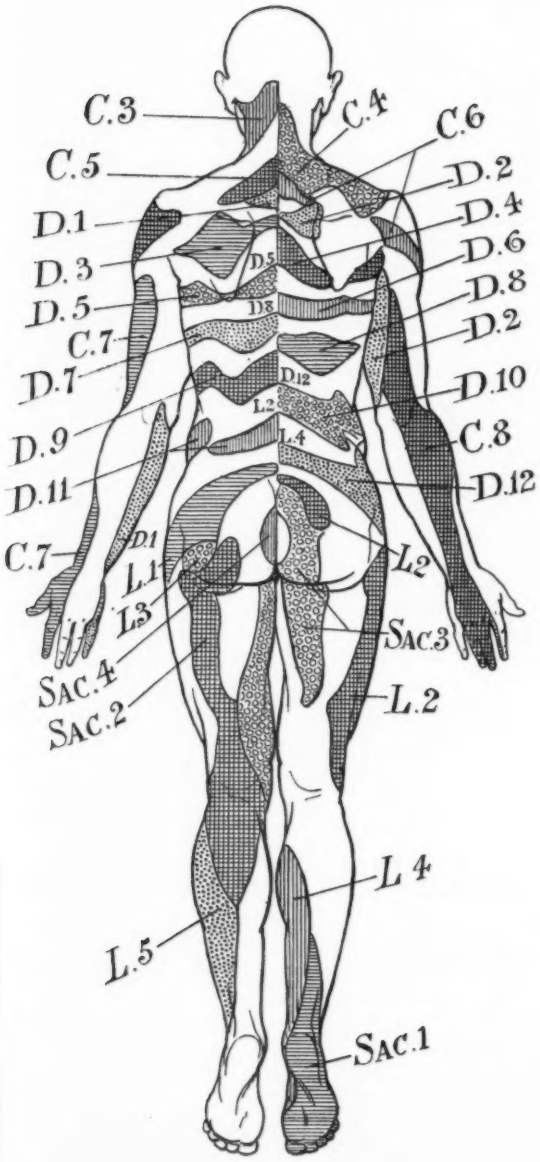
An attempt to represent on one diagram the areas occupied by the eruption of herpes zoster. Of the areas here represented the following have been confirmed by microscopical examination :—

Cervical 3.—(Case 6 and Case 17.)
Cervical 4.—(Case 10.)
Dorsal 2.—(Case 7.)
Dorsal 4.—(Case 11 and Case 14.)
Dorsal 6.—(Case 3 and Case 13.)
Dorsal 7.—(Case 2 and Case 9.)
Dorsal 8.—(Case 16.)
Dorsal 11.—(Case 5.)
Dorsal 12.—(Case 4, Case 8 and Case 12.)
Lumbar 1.—(Case 1.)

Thus we consider that the areas on the neck and trunk are more likely to be correctly mapped out than those on the limbs. Moreover, the difficulty in determining the distribution of these areas on the limbs is heightened by the rarity of zoster on the extremities (*vide* p. 394).




C.4
C.3
D.3
C.5
D.2
D.5
D.4
D.3
D.7
D.6
C.6
D.9
D.11
D.8
C.7
D.2
L.1
D.10
C.8
D1
D.12
L.2
L.3
L.4
L.5
SAC.1


C.3
C.4
C.6
C.5
D.2
D.1
D.4
D.3
D.6
D.5
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C.7
D.2
D.7
D.10
D.9
C.8
D.11
D.12
C.7
L.2
L.1
L.3
Sac.3
Sac.4
L.2
Sac.2
L 4
L.5
Sac.1

corresponding nuclei are healthy, and the significance of the change is doubtful.

In the remainder of the medulla and in the upper part of the spinal cord there is no change referable to the herpes.

Case 20.—John A., aged 38. Admitted to Claybury Asylum September 27, 1898. Died March 13, 1899.

SUMMARY.

A case of dementia paralytica, who suffered from a slight attack of herpes zoster over the 10*th dorsal area (fig.* 20) 139 *days before his death from broncho-pneumonia.*

No scars were seen on the body at death, and an examination of the nervous system failed to reveal any lesions corresponding in any way with the herpes zoster.

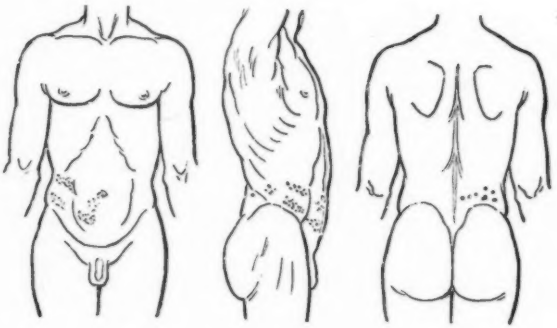

FIG. 20.

To show the distribution of the eruption in Case 20.

He was so grossly demented on admission that no trustworthy history could be obtained.

He was a fat, well-nourished general paralytic, with slow, slurred speech. Had delusions of grandeur and was rambling and incoherent in conversation. His pupils reacted to accommodation but not to light. Knee-jerks exaggerated.

By the end of October he was wet and dirty, sitting all day by himself. His speech had become much more hesitating.

On October 25 an eruption of herpes zoster appeared over the 10th dorsal area (fig. 20). In front the eruption was fairly profuse but behind was poorly marked. It was not a severe outburst.

By February, 1899, he was confined to bed entirely, and he died on March 13 of hypostatic pneumonia, 139 days after the appearance of herpes zoster.

Post-mortem Examination.

Twenty-four hours after death. The body had been kept in the cold chamber at a temperature just below freezing-point.

Post-mortem rigidity was not present. Nutrition of body fair.

Brain.—In the subdural space in the left posterior and middle fossæ was a thin, organised, rusty membrane, the earliest form of pachymeningitis hæmorrhagica. The pia over the frontal and parietal lobes was markedly thickened and opaque. Over the temporal and occipital lobes some thickening was seen but it was less marked. Gelatinous exudation was present in the subdural space.

The brain was moderately wasted, the right hemisphere weighing 563 grammes, the left 560 grammes. There was slight general wasting of the frontal and parietal convolutions. Striæ of the cortex invisible. Puncta vasculosa well marked. Both ventricles were slightly dilated, granular, and filled with clear fluid.

The cerebellum was normal.

The fourth ventricle was granular.

Thorax.—The right lung was in an advanced stage of broncho-pneumonia throughout and presented many areas of collapse. The upper lobe was in a more advanced stage of disease than the lower. The bronchi were full of semi-purulent mucus.

The upper and lower lobes of the left lung were adherent to the chest wall by recent adhesions, and the posterior surface was covered with a thin layer of organised lymph. The upper lobe was in an advanced condition of broncho-pneumonia. The lower lobe showed the same change in a less advanced form.

The heart was normal except for slight thickening and puckering of the mitral valve.

The aorta showed the first stage of atheroma.

Abdomen.—Liver congested but otherwise normal.

Kidneys normal.

Spleen normal.

Microscopical Examination.

(*a*) *Posterior Root Ganglia.*

The 8th, 9th, 10th, 11th and 12th dorsal ganglia were hardened in 96 per cent. alcohol, embedded in paraffin and cut in series. They were stained by Nissl's methylene blue method and counterstained with safranin or eosin.

In no case could we find any gross abnormality in the capsule, cells, or interstitial tissue of any of these ganglia.

(*b*) *Posterior Nerve-roots.*

The 9th, 10th, 11th and 12th posterior nerve-roots on both were hardened in Müller's fluid and stained by Marchi's method. The stain succeeded admirably, but no root showed any degeneration.

(*c*) *Spinal Cord.*

Every segment of the spinal cord was stained by Marchi's method and by Schäfer's modification of the Pal method (Marchi-Pal).

The cord showed well-marked Marchi degeneration in both the direct and crossed pyramidal tracts on both sides. This acute degeneration appeared to be accompanied in the dorsal region by slight and doubtful sclerotic changes.

The posterior columns and root zones were everywhere absolutely normal.

(*d*) *Cortex.*

Portions of the cortex from the ascending parietal and Broca's convolutions on the right and left sides showed thickened membranes, dilated vessels and marked absence of the tangential fibres.

Case 21.—William C., aged 49. Admitted to Claybury Asylum November 26, 1895. Died March 14, 1897.

SUMMARY.

On admission showed marked dementia paralytica. Towards the end of the summer of 1896 *he developed a crop of herpes zoster over the area in fig.* 21. *He died about eight months after the eruption. No change could be found corresponding to the herpetic eruption.*

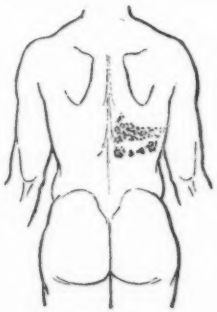

FIG. 21.

To show the distribution of the eruption in Case 21.

No history of any importance could be obtained.

On admission.—He was suffering from marked dementia, and his memory was much impaired. His speech was distinct but tremulous and was not slurred. There was considerable tremor of the lips and tongue. On the body were scars of tertiary syphilis. The pupils were equal and reacted normally. Knee-jerks normal.

Progress.—He became more demented, and at some time towards the end of the summer of 1896 (date not noted in the case-books of the asylum) he developed herpes zoster over the area in fig. 21, taken from a photograph. This attack left a permanent sore on his back, owing to his filthy habits and to constant scratching. He died on March 14 from pneumonia, mainly affecting the base of the right lung.

Post-mortem Examination.

Twenty hours after death.

On the back, in the position representing part of the area affected by the herpetic eruption, is a purplish patch of superficial ulceration. This patch lay over the posterior portion of the eleventh rib and the last intercostal space, and extended as far forwards as the anterior axillary fold.

He was well nourished and *post-mortem* rigidity was well marked.

The right pleura was thickened and adherent from recent pleurisy over the lower lobes. The whole of the lower lobe of the right lung was solid, and presented the appearance of gray hepatisation. The upper lobe was œdematous and congested.

The left pleura was normal. The left lung was somewhat œdematous and congested, but otherwise normal.

Heart normal.

Aorta somewhat atheromatous.

Liver pale, fatty, and somewhat soft.

Kidneys normal.

Spleen soft and flabby.

The brain weighed 50 ozs. (1,415 grammes). Both gray and white matter appeared normal; the ventricles were not granular, and the pia-arachnoid was not thickened or adherent and stripped well.

Microscopical Examination.

The following parts were examined—(*a*) a series of posterior root ganglia, (*b*) a series of spinal nerve roots, (*c*) certain peripheral nerves, (*d*) the spinal cord.

(*a*) *Posterior Root Ganglia.*

The 8th, 9th and 10th dorsal ganglia were hardened in Müller's fluid and stained by Marchi's osmic acid method, by

Weigert and Weigert-Pal with hæmatoxylin, and Pal counter-stained with eosin.

In no case could any change be discovered in the vessels or capsule. The method of hardening precluded the use of Nissl's method of cell staining, but the remaining methods showed no loss of cells in any ganglion.

(*b*) *Posterior Nerve-roots.*

The posterior nerve-roots of the 8th, 9th and 10th dorsal on both sides were examined by Marchi and the Marchi-Pal methods, and no change could be detected, either recent or remote.

(*c*) *Peripheral Nerves.*

The peripheral nerves emerging from the 8th, 9th and 10th dorsal ganglia on both the right and left sides were stained by Schäfer's modification (Marchi-Pal), by Marchi, and by Pal's method.

In no case was any profound change seen, except that perhaps the nerve from the 8th dorsal ganglion on the right side contained fewer fibres than that from the left ganglion on the same level.

(*d*) *Spinal Cord.*

From the level of the 11th to that of the 6th dorsal every segment was cut and stained by the (1) Marchi, (2) Weigert, and (3) Weigert-Pal methods.

In no case was there any sclerosis or acute degeneration in the posterior columns or root zones. The cord was otherwise normal.

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DESCRIPTION OF PLATES.

Plate 1.

Fig. 1.—From a coloured drawing of a longitudinal section of the 7th dorsal ganglion of the right side in a case that died eight days after the outburst of the eruption (Case 2). This section is stained with hæmatoxylin and eosin.

Fig. 2A.—From a coloured drawing of the 7th dorsal ganglion of the normal (left) side in Case 9. Death occurred 153 days after the outburst of the eruption. Stained by Marchi's method, and counterstained by van Gieson's picro-hæmatoxylin method.

Fig. 2B.—The 7th dorsal ganglion of the abnormal (right) side in the same case, stained by the same methods.

Plate 2.

Fig. 1.—Drawing from a portion of the 4th dorsal ganglion of the right side in Case 14. This ganglion was invaded by lympho-sarcomatous growth.

Fig. 2.—Photomicrograph of a portion of the same ganglion under a higher power.

Plate 3.

Fig. 1.—A low-power photograph of the 11th dorsal ganglion of the left side in Case 5. The more darkly-stained areas are foci of small round cells.

Fig. 2.—A photograph under a higher power of the inflammatory focus surrounded by a white ring in fig. 1.

Plate 4.

Fig. 1.—Photograph of one of the inflammatory foci in the 3rd cervical ganglion of the left side in Case 16.

Fig. 2.—Photograph under the same power of a portion of the 3rd cervical ganglion of the right side in the same case. Both ganglia were cut in the same block, fixed on the same slide, and stained together by Nissl's method.

Plate 5.

Case 6.

Three drawings of transverse sections of the 3rd cervical ganglia of both sides in a case in which the herpetic eruption was distributed over the 3rd cervical area of the left side.

The three right-hand figures are from the normal ganglion, those on the left from the diseased one; in the latter the pale area at the lower end of each section indicates the lesion. This area was composed almost entirely of fibro-cellular tissue, and contained no nerve-cells and no nerve-fibres.

The sections were all stained with osmic acid and hæmatoxylin for the display of nerve-fibres, and healthy fibres are indicated by black dots, the small circles representing nerve-cells.

Fig. 1 is taken from that end nearest the posterior root.

Fig. 2 from the centre of the ganglion.

Fig. 3 near to the peripheral nerve.

Abbé drawing apparatus $\frac{2.5}{1}$.

Plate 6.

Figs. 1A and 1B are from Case 10, and are drawn from transverse sections of the right and left 4th cervical ganglia, stained with logwood only.

In fig. 1B an extensive pallid area, almost entirely bereft of nerve-cells and nerve-fibres, is seen at the top of the drawing. This is the lesion. Fig. 1A shows the normal left ganglion for comparison. Both sections come from about the middle of the ganglion.

Abbé drawing apparatus $\frac{2.5}{1}$.

Fig. 2 is from Case 13, and is a drawing of the 6th dorsal ganglion of the right side. This section came from about the middle of the ganglion, and the lesion is seen lying to the right of the field. It is recognisable as a pallid area in which no nerve-cells or nerve-fibres are present, and over which the ganglionic sheath is thickened. The section was stained with osmic acid and iron alum for the display of healthy nerve-fibres, and such fibres are shown in the drawing as black dots or lines. The herpes occurred 790 days before death. The arrow points in the direction of the anterior root.

Abbé drawing apparatus $\frac{4.0}{1}$.

Plate 7.

Case 7.

Four drawings, made with an Edinger apparatus, of Marchi-stained longitudinal sections of the 2nd dorsal posterior root ganglion of the left side, with annexed roots and peripheral nerve.

The first drawing illustrates a section made rather to one side of the ganglion, and shows complete destruction of the ganglionic substance (indicated by cross-hatching). The anterior root, which is normal, lies in the upper part of the field; on the right the roots pierce the dura spinalis, and the peripheral nerve is to the left, and shows signs of sclerosis (under a high power it also shows remains of degeneration).

In fig. 2, which illustrates a section more towards the centre of the ganglion, a field occupied by healthy nerve-fibres and nerve-cells is appearing in the distal segment of the ganglion.

In fig. 3 the destructive lesion is disappearing, three small foci of disease alone remaining.

In fig. 4, which is drawn from a section towards the edge of the ganglion opposite to that shown in fig. 1, the body of the ganglion appears to be normal.

Plate 8.

The two upper figures are from Case 8, and are Edinger drawings of longitudinal sections of the 12th dorsal ganglion of the right side, stained by the method of Marchi. A typical focal lesion is seen in the upper part of the ganglionic field. Death occurred 103 days after the eruption first appeared.

The two lower figures are from Case 4, and show the appearances seen in longitudinal sections of the 12th dorsal ganglion of the left side, stained by the method of van Gieson (hæmatoxylin and picro-fuchsin). The blurred area in the upper portion of the field represents the position and extent of the ganglionic lesion. Note the hæmorrhage in the centre of the peripheral nerve in the third figure. The herpetic eruption occurred only thirteen days before death.

Plate 9.

Case 18.

Photographs of right and left Gasserian ganglia. These photographs are explained by the underlying skeleton plan.

Plate 10.

Fig. 1.—Twelve drawings showing the degeneration found in Case 7; it entered at dorsal 2 and was traced up to cervical 1. In dorsal 3 and 4 a few degenerated descending collaterals are indicated.

FIG. 2.—Six drawings illustrating the degeneration which occurred in Case 6; it entered at cervical 3 and was traced well up into the medulla, terminating in the nucleus cuneatus.

PLATE 11.

FIG. 1.—A series of six drawings to show the degeneration in Case 5. The degenerated fibres enter at the level of the 11th dorsal root and can be traced up to the level of the 6th dorsal.

FIG. 2.—A series of six drawings to show the degeneration in Case 3. The degenerated fibres enter at the level of the 6th dorsal root and can be traced to the level of the 3rd dorsal. A few descending collaterals are seen at the level of entry of the 7th dorsal root.

FIG. 3.—A series of six drawings to show the degeneration in Case 9. The degenerated fibres enter at the level of the 7th dorsal root and can be traced as high as the level of the 2nd dorsal. Descending collaterals can be seen at the level of the 8th dorsal root.

These drawings were made with the Edinger apparatus.

PLATE 12.

Outline drawings, made with an Edinger drawing apparatus, showing the degeneration displayed by the method of Marchi in the spinal cords of Cases 4, 8, and 17.

FIG. 1.—Six drawings from Case 4, in which the herpetic eruption was distributed over the 12th dorsal area of the left side, and the distribution of the degeneration which occurred in the corresponding posterior spinal root fibres, is represented.

FIG. 2.—Six drawings from Case 8, where the eruption also lay over the 12th dorsal area, but affected the opposite side. The degeneration in the pyramidal tracts represented in these drawings was the result of cerebral softening of thrombotic origin.

FIG. 3.—Six drawings from Case 17, in which the eruption was distributed over the 8th dorsal area of the left side and degenerated fibres enter in the corresponding posterior spinal nerve-root. This patient was a tabetic general paralytic, and the shaded area in the posterior columns indicate the site where tabetic sclerosis existed, while in the pyramidal tracts the acute degeneration commonly found in cases of general paralysis is represented.

PLATE 13.

Case 18.

Drawings to show the distribution of the degeneration in the sensory root of the right 5th cranial nerve, as brought out by the method of Marchi in a case in which the herpetic eruption was distributed over the area supplied by the inframaxillary division of that nerve.

FIG. 1 shows the entire root at its point of entry into the pons, and collections of blackened degenerated fibres are clearly visible in the outermost bundles of the sensory root. The motor root is cut obliquely and is shown lying just internal to the sensory root.

FIG. 2.—A degenerated portion of the sensory root just after entering the pons.

FIG. 3.—The sensory root in the first part of its downward course—diseased fibres cut rather obliquely. The fibres on the right are transverse pontine ones. The arrow points in the direction of the 4th ventricle.

FIG. 4.—At the level of the issuing 7th root, which is represented to the left (internal) of the 5th root. Note that there is comparatively little degeneration in the lower portion of the field.

FIG. 5.—At the level of the 8th nucleus. Between the root and the surface lie the external arcuate fibres, and on the left side internal arcuate

fibres enter and split up the root. Degeneration is still visible, and, as in the last figure, it principally occupies the upper two-thirds of the field.

FIG. 6.—At the level of the 1st cervical root the degenerated 5th root lies just below the surface external and dorsal to the substantia gelatinosa Rolandi, into the dorsal portion of which degenerated fibres stream.

Abbé drawing apparatus $\frac{2.5}{1}$.

PLATE 14.

FIG 1.—A photograph of a transverse section of the spinal cord of Case 9 at the level of entry of the degenerated fibres. Low power.

FIG. 2.—A photograph under a higher power of a transverse section of the spinal cord in Case 3, at the level of entry of the degenerated fibres. The lower part of this figure is towards the posterior surface of the cord; the lighter portion towards the left of the figure represents the posterior horn of the affected side.

PLATE 15.

Two Photographs of Longitudinal Sections of the Spinal Cord from Case 6.

FIG. 1.—A low-power view showing the disposition of degenerated posterior root fibres immediately after entering the cord. The periphery is on the left. The section is longitudinal and parallel with the posterior horn. $\frac{90}{1}$.

FIG. 2.—A longitudinal section of the same fibres after entering the cord. The figure gives a good idea of the degree and extent of the degeneration to be found in the cord in typical cases of zoster. $\frac{120}{1}$.

PLATE 16.

FIG. 1. Case 4.—A photomicrograph of some teased fibres of the 12th dorsal posterior root of the left side, stained by the method of Marchi. The two upper fibres clearly show acute degenerative changes. $\times \frac{300}{1}$.

FIG. 2. Case 6.—A transverse section of the 3rd cervical anterior and posterior roots central to the ganglion, at the point where they pierce the dura. In the left-hand portion of the sensory root, which lies above and to the left, some sclerosed unstained bundles are to be recognised; these indicate the remains of herpetic degeneration. Healthy bundles are stained black. Method of Schäfer $\times \frac{45}{1}$.

FIG. 3. Case 13.—Drawing of a transverse section of the affected peripheral nerve 1 cm. distal to the ganglion, made with an Abbé drawing apparatus from a formol-hardened osmic acid stained preparation. To the right a bundle is seen which to a large extent is deprived of nerve-fibres, and three other bundles are not quite healthy.

FIGS. 4 AND 5. Case 13.—Drawings of the above nerve more highly magnified. Fig. 4 is a portion of the healthy bundle lying to the left. Fig. 5 is a portion of the sclerosed bundle lying to the right.

A NOTE ON THE STAINING OF BRAIN IN A MIXTURE OF METHYLENE BLUE AND PEROXIDE OF HYDROGEN—A *VITAL* REACTION IN *POST-MORTEM* TISSUE.

BY JOHN TURNER, M.B.ABER.

THE oxygen of the air has such a marked effect on brains stained by Ehrlich's *intra-vitam* method, that it occurred to me to try a mixture of methylene blue and peroxide of hydrogen on *post-mortem* tissues.

The result obtained was encouraging, for to a certain extent the tissues so treated took on a "vital" staining reaction and one no longer got the usual effect of methylene-blue, there being no appearance of Nissl-bodies in the cells, and the finest ramifications of certain nerve-cell processes were displayed with great distinctness.

METHOD.

The following is an account of the method I now use, and by which good results are generally got.

Small pieces of the cortex and subjacent white matter, not more than one-eighth of an inch thick, are placed direct into a mixture of six parts 1 per cent. solution of methylene blue (patent B.X.) and one part peroxide of hydrogen solution.

The blue solution must be old; at any rate, I have not succeeded yet in getting results with a freshly-made solution. It is not polychrome, although kept exposed to light and air in a wide-mouthed unstoppered bottle for a year.[1]

[1] This is the time that the solution I have been using was kept; but some made up only two to three weeks ago, and well aerated and exposed to sunlight, begins to give the reaction. I have also got good results from a solution made only a few months, and which had been used for staining *in toto* pieces of alcohol-hardened brain.

Very good results are obtained in the case of bodies twenty-four hours dead, and I do not think that material got quite shortly after death stains any better than that which has been dead many hours.

When the piece of brain is placed in the staining mixture a brisk evolution of gas takes place, which sometimes blows the stopper of the bottle out unless it is tied in.

After eleven days the pieces are taken out of the methylene blue mixture and put into 10 per cent. solution of molybdate of ammonia and left all day and night, then washed during the following day under a running tap till the evening, when they are placed in absolute alcohol and kept cool by running water. After a few hours the alcohol must be replaced by fresh. The pieces are left in spirit all night, and the next morning put into xylol for one hour, and then into fresh xylol for another hour, and then into paraffin for two hours, and thick sections cut. These are placed on xylol on the slide and all the paraffin washed out, and then decolourised for a few seconds in a mixture of equal parts of creosote and aniline oil, washed again on the slide in xylol, and mounted in Canada balsam, and the cover-glass very carefully pressed down to flatten out the section.

The staining appears to be permanent, for sections prepared two years ago show no deterioration.

In all cases the reaction is patchy, parts only of the section showing it, and these parts appear paler and generally have a faint pink tinge. I have never yet succeeded in getting the first layer of the cortex to take on the reaction.

Appearances.

Cerebral cortex.—In the successful parts the ground substance is hardly coloured, the pyramidal cells (and probably the giant-cells when healthy) show no signs of any chromophilic substance, the cytoplasm of the cell (as by *intra-vitam* staining) is a pale, uniform blue, and the apex and dendrites in the vicinity of the cell-body are similarly coloured, but in some cases at a little distance they both stain densely. The nucleus in these cells appears very prominent and plump; it

is strongly outlined and filled with dark granules, so that it is by far the darkest part of the cell. The nucleolus is often obscured; when visible it is *pale* and ill-defined in healthy cells (see figs. 4 and 5).

Around these cells, and extending along the apex and dendrites, are seen a number of fine beaded fibrils, arranged as a network all over the cell-body and its processes (see figs. 1 to 5). The branches of this network appear to be given off from the beads, and not from intermediate portions of the fibres (fig. *C*).

This appearance was fully described by Drs. W. A. Turner and W. Hunter, as seen after *intra-vitam* staining of animals' brains.[1]

It has never hitherto, as far as I know, been demonstrated in the human brain.

The beaded fibrils can be seen arriving at the nerve-cells from different places; some pass on to the apex here and there along its course, coming from the adjacent matrix, others similarly to the dendrites, and the fibrils from these different sources appear to anastomose into a continuous network which, as before said, envelopes both the cell-body and its extensions.

I have been able to follow this arrangement for a considerable distance over the apex and along outstanding dendrites (fig. *B*).

Besides the above-described pale cells, others (see fig. 5) are seen, relatively few in number, which stain very darkly indeed, both the body of the cell and its processes to their furthest ramifications.

These cells are generally small and pear-shaped or multiangular, and they occur in all but the first layer of the cortex.

Although my tissues were from diseased subjects, yet, as these cells occur in all of them, and as they are mentioned by W. A. Turner and W. Hunter as seen in the animals they experimented on, they may with considerable certainty be taken as representing a normal type of cell.

[1] "A Form of Nerve Termination," by Drs. W. A. Turner and W. Hunter, BRAIN, Spring Number, 1899.

Now the processes of these cells, which can often be followed for 200 or more μ, are at first shaggy in outline, and as they get smaller they present little varicose swellings along their course, and eventually in their finest divisions they appear identical to the beaded fibrils which form the network about the pale pyramidal cells. In some cases, where a dark and a pyramidal pale cell have been favourably situated in the section, I believe I could directly trace the beaded dendrite into the beaded network, but as the fibrils we are dealing with are so excessively fine, it is impossible even with a one-twelfth oil immersion to be certain on this point (fig. *A*).

Drs. W. A. Turner and W. Hunter derive this beaded network from the terminal branching of collaterals given off from the axons of other cells, and not from dendrites as above described.

In my preparations the axis cylinders, as seen in the white matter adjacent to the cortex and where they course up through the lower part of the cortex, always appear smooth in contour and very pale. This to a certain extent corroborates the supposition that the darkly-stained fibrils of the network comes from the similarly darkly-stained dendrites of the small darkly-stained cells. But as we have seen that sometimes the processes of pale pyramidal cells take on a dark stain at a certain distance from their parent cell, it is quite possible that the collaterals also may stain deeply although the axis cylinder stains lightly. Apart from this, however, I think that the similarity of the fine branches of undoubted dendrites with the fibrils forming the beaded network, is a very strong point in favour of the supposition that the latter is an extension of the former.

Given off from the sides of the shaggy dendrites of the dark cells are very fine lateral processes which may end in a bead, or may have more than one in its course; possibly these represent the thorns and gemmules of silver preparations (figs. 6 and *D*).

Cerebellar cortex.—So far I have done very little with this part, but the sections from a fairly successful specimen showed a number of smoothly contoured wavy fibres running

parallel to the plane of the section (which was from a piece of tissue cut in a sagittal direction from the cerebellum) in the lower fourth of the molecular layer.

Among these fibres could be seen an occasional small (12 μ) darkly-stained pear-shaped cell, from which processes which appeared identical to the above-mentioned fibres were given off from either end.

These fibres give off right-angle branches at intervals running towards the granular layer.

Similar fibres course along the branches of the Purkinje cells and pass over the cell body in a longitudinal direction, forming a basketwork around it, and this basketwork often appears to end in a dense cluster a little distance beneath the cell, exactly as described and illustrated by Dr. Alexander Hill.[1] I have not noticed any anastomosing branches between the fibres around the Purkinje cells, and they show no signs of beads. Perhaps they are not nerve but neuroglia fibres?

Although the method here described is capricious and uncertain in its action, yet it shows the possibility of staining in *post-mortem* tissue delicate structures which have hitherto only been revealed by methods inapplicable to human subjects.

We may, I think, reasonably expect that with further experience, and when we know more about the conditions on which the staining depends, to get more certain results.

Even in its present imperfect state it may enable us to further unravel the very complicated inter-communications which exist between nerve-cells, and possibly it may prove of service in studying the pathology of the nervous system.

Addenda.

No. 1.—It is advisable to take out the stopper of the bottle containing the staining mixture and the piece of brain occasionally to let out the gas evolved, and to shake up the solution from time to time.

No. 2.—Further trials make it probable that the reaction depends to a large extent on the length of time the tissue is left in the staining fluid.

[1] Brain, 1896, xix., pp. 22-25, fig. 6.

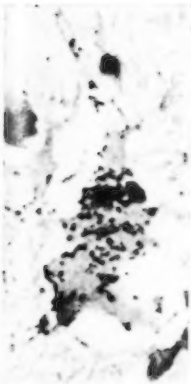


FIG. 1.

FIG. 2.

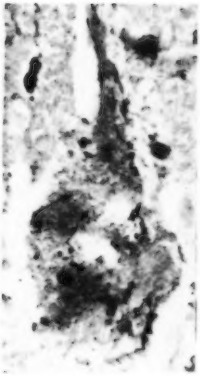


FIG. 3.

FIG. 4.

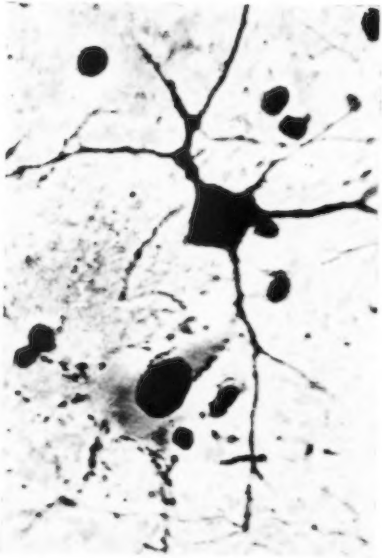


FIG. 5.

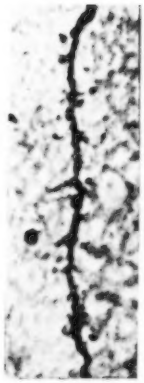
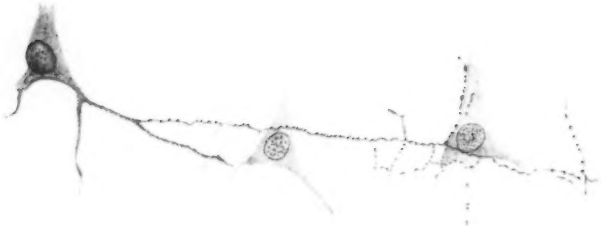


FIG. 6.



A

B

C D

Bale & Danielsson, Ltd., Lith.

I have got a reaction in pieces of brain left eleven days, whereas in other pieces of the same brain left only four days no result was obtained.

Methylene blue solutions are preservatives of brain, so that no decomposition takes place even after weeks in the solution.

No. 3.—Since the above account was written I have observed beaded fibrils quite similar to those seen around the cerebral cells forming a network around the Purkinje cells of the cerebellum.

DESCRIPTION OF FIGURES.

No. 1.—A giant-nerve cell, the body of which is out of focus, showing the beaded network surrounding it. × 600.

No. 2.—Three pyramidal cells; in the uppermost the beaded network is seen over the apex and all round the cell body. The beads are also clearly visible along the sides of the other two cells. × 600.

No. 3.—A giant-nerve cell, out of focus, showing portions of beaded network upon it. × 600.

No. 4.—A pyramidal cell with pale uniform cytoplasm, dark nucleus, and pale irregularly-outlined nucleolus. Beads are seen on the cell-body and apex, but the connecting fibrils are not visible in the photograph, although seen in the section from which it is taken. × 600.

No. 5.—Small darkly-stained cell with processes of irregular contour, also a pale pyramidal cell with dark nucleus. The beaded network is shown at the edges of this cell and over its dendrites. × 600.

No. 6.—A delicate darkly-stained nerve-fibril with lateral projections and beads. × 1,200.

Note.—No two of the figures of nerve-cells are from the same case.

A shows a darkly stained cell with a shaggy dendrite passing to, and apparently breaking up into beaded fibrils around a pale cell.

B.—Apex of a pale cell with beaded fibrils about it.

C.—Beaded network over a pale cell (the cell is not figured). The nutrient vessel of the cell is seen.

D.—Two fine fibrils with fine lateral beaded processes.

REPORT ON A SUBDURAL BLOOD CYST.

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THE condition about to be described is of great pathological interest, being occasionally and, on the whole, rarely met with in asylums, and still more rarely in workhouse infirmaries and hospitals.

CLINICAL HISTORY.

Patient was a male, 57 years of age, whose mental condition (dementia) was stated to have been developing during the previous two years. On admission, he was found to be extremely demented and very restless, and could only with difficulty be induced to reply to questions. If pressed to answer he would commence to groan and become emotional. He showed great lack of intelligence, but was able to feed himself. He was feeble, emaciated, and anæmic. Tongue not tremulous. Pupils equal. Knee-jerks present. Some incontinence of urine. The area of superficial cardiac dulness was enlarged, a systolic bruit was present at the heart's apex, and the arteries were thickened. Breath sounds faint. Urine pale, acid; specific gravity, 1015; contained albumen.

The patient, after admission, continued restless and feeble-minded. At the end of a week it is noted that he appeared to have had a slight stroke, affecting the left side. There was much rigidity about the shoulders, but he was able to move his arms. Head and eyes turned to the right. Constant dribbling of urine. Mentally there was complete dementia.

Four days later it was noted that the hemiplegic symptoms had passed off, but the mental condition remained unchanged.

At the end of another week it was observed that there was a good deal of rigidity about the left arm, especially at the shoulder. Nothing could be got out of him; he lay in bed, groaning at times, but taking nourishment fairly. He continued in this condition until his death occurred, twenty-two days after the left-sided

weakness had been noted. Shortly before death some râles were observed at the bases of the lungs posteriorly.

Patient's occupation was that of a driller.

There were no epileptiform attacks, nor any anasarca or ascites during patient's stay in the asylum.

The above is an abstract of the case-book notes (for which I am indebted to Dr. C. W. Ensor). The following additional information was subsequently obtained from the patient's wife.

Patient's father died at 62 years of age, of dropsy; he had "fits" lasting two or three weeks at 50 years of age, but not subsequently. Patient's mother died at 42 years of age, of some lung trouble. Patient had no brothers, but two sisters, both dead, one of typhoid and another of an illness attributed to a bad smell from a drain. No other near relatives. No consumption or gout in family.

Patient was a quiet man, employed all his life as a mechanic at a locomotive engine works. He was a steady worker. He drank little, on the average not more than two glasses of beer a week. Did not take spirits. Was averse to drink, which made him excited, because it caused him to suffer subsequently from bad headaches. Did not smoke much. Never had any fever nor sunstroke (except the illness occurring thirteen years ago, described below, is of this nature). No injury to the head, no exposure to lead, no winter cough, never suffered from squint or weakness of a limb. Never had any fits. Was ruptured at 16 years of age, and always wore a truss.

Patient was married at 26 years of age. His wife had three miscarriages after marriage; the first at about four months' pregnancy, the second and third at about six months'; she did not subsequently become pregnant. The wife's health has always been good. Three weeks after marriage patient was troubled with a sore throat; he had much pain, and remained in bed four or five days, but there was no hoarseness or loss of voice.

Patient was subject to headaches all his life.

Twenty-four years ago patient had an illness lasting several weeks, the nature of which is not clear; complete recovery occurred. Thirteen years ago had another attack of illness of doubtful nature, not apparently severe, from which he recovered at the end of two or three months. During this illness the left shoulder was the seat of much pain.

Another attack of influenza occurred six years ago. Patient was ill seven weeks. Complete recovery occurred.

Three years and ten months ago patient had a second attack of influenza. He remained in bed for eight weeks. He had much pain in the back, particularly in the lumbar and sacral regions. When he left his bed he was unable to move about much. He tried to work, but was unable to do so, because of the pain in his back. He used to get excited and lose his temper, and would follow his wife about like a child. About this time he used to have cramp in the calf-muscles; and he suffered from sore throat, which left him hard of hearing. A change occurred in his disposition. He became emotional, would strike his wife without any cause, and exhibited suddenly, according to his wife's account, difficulty of speech, that is to say, he tried to speak, but could not. Patient, when this occurred, became quite prostrate; next day he was restless, getting in and out of bed, and he exhibited much mental defect, being unaware of the time of day and not knowing what was going on around him. He passed his urine and fæces into the bed.

Patient was removed into the workhouse infirmary three months after the commencement of the second attack of influenza. Here, according to the statement of his wife, who visited him regularly, his condition got on the whole steadily worse, though at times some improvement occurred, followed by a change for the worse. At first he appeared to gain flesh, but this may have been merely apparent, for his face became puffed up, and the abdomen swollen, both of which his wife attributed to "dropsy." Most of this time he was in bed, but sometimes he walked a little about the ward, the last occasion being about two months before admission to the asylum. When he moved about the ward his wife did not notice any weakness of the limbs on one side of the body, nor did she at any time notice any disorder of gait. During his stay in the workhouse infirmary patient was never able to recognise his wife.

Post-mortem Examination.

Some difficulty was experienced in removing the skull-cap, which was thin but dense, owing to the existence of adhesions on the part of the dura mater. This membrane, which was not thickened, exhibited on its inner surface a thin yellowish-brown pellicle at the base and on the left side over the vertex, while on the right side a large moderately

firm flattened sac of a dark reddish-brown colour lay in the subdural space over the cerebral hemisphere, which was considerably flattened (figs. 1 and 2). This sac was about 14 centimetres long by about 10 centimetres broad, and had a maximum thickness of $2\frac{1}{2}$ centimetres. At the edges it thinned off and became continuous with the rusty pellicle already referred to. Its contents consisted partly of a friable, brownish-black, soft solid material, and were in part made up of a dark-brown fluid not draining away readily when the sac was incised. The wall of the sac was firm and of a grayish-brown colour; it was rather firmly adherent both to the dura and to the pia arachnoid, so that some difficulty was experienced in separating it from these membranes. The thin rusty pellicle, on the other hand, was closely adherent only to the inner surface of the dura mater.

The falx cerebri was considerably displaced to the left (figs. 1 and 2). This displacement, which was striking in its aspect both when viewed from above (fig. 1) and in frontal section (fig. 2), was most marked opposite the middle of the vertex, where also the sac was thickest. The pia arachnoid was slightly thickened and opaque, chiefly over the vertex. The subarachnoid space contained clear yellowish fluid, and the sulci lying between the cerebral convolutions were widened. The gyri were wasted.

On making a frontal section of the cerebrum and the subdural formation after hardening (fig. 2), additional information concerning the formation of both was obtained. The wall of the subdural sac was well defined and sharply limited from its solid and semifluid contents. Its general thickness, which was fairly uniform, was about 1 millimetre. At the angle of junction of its outer and inner surfaces, however, it was much thicker, as is seen in the second figure. The contents, after hardening, were in part solid, exhibiting an imperfectly stratified arrangement and very friable, and in part consisted of fluid containing solid particles freely suspended. On the surface of the sac turned towards the hemisphere sinuous grooves were seen which corresponded to the large veins observed on the surface of the brain. Along these grooves, which were well seen before, as well as

after, hardening, the surface of the sac was whitish in aspect.

The cerebrum was displaced to the left by the subdural cyst, both hemispheres being alike affected, and the structures, which are normally mesial in position, lay to the left of the middle line (fig. 2). The alteration in form was greatest on the right side, where the hemisphere was considerably flattened on its upper and outer aspect. The island of Reil was especially distorted on this side. The basal ganglia and the third and lateral ventricles were also markedly and unequally distorted. The corpus callosum is shown in the section to be displaced to the left.

The ventricles, like the subarachnoid space already described, were somewhat dilated, the distension, however, not being considerable (fig. 2). Thus, in addition to the presence of a large sac in the subdural space and the corresponding amount of brain atrophy which this causes, there is an additional degree of atrophy revealed by the excess of fluid in the ventricles and subarachnoid space. It is not, however, possible from the pathological appearances to determine how far the loss of brain substance is to be regarded as due to the presence of the subdural sac and how far it is to be viewed as part of the change in the brain so frequently found in senile dementia.

No focal lesions were found in the encephalon. The cerebellum was adherent to the dura mater, covering the posterior fossa on the left side. The spinal cord presented no naked-eye change.

The weight of the entire brain was 1,040 grammes; the cerebellum weighed 110 grammes; the pons and medulla 15 grammes; and the subdural sac 115 grammes.

The arteries at the base of the brain were healthy, as were also the venous sinuses.

The lungs were congested and œdematous at both bases. The mitral and tricuspid valves of the heart were thickened. The heart-muscle was firm. There was commencing atheroma at the root of the aorta. The kidneys showed some degree of chronic interstitial nephritis. The remaining viscera showed no gross change.

Inguinal hernia was present on the right side. There was marked phimosis. There was no distinct scar on the penis, nor any punched-out scars on the body, nor any thickening of the ribs or of the long bones of the limbs.

The body was much emaciated.

Microscopical Examination.

A section of the wall of the sac shows it to consist of fairly dense connective tissue, containing an abundance of blood-vessels, a large number of which are of considerable size and very thin walled, together with numerous cells (figs. 3, 4, and 5).

The connective tissue strands are for the most part arranged parallel to the surface and intersect each other at all angles. They vary much in size, from the finest threads to relatively coarse bundles (fig. 5). Lying upon them are large flattened elongated nuclei, round which no well-defined cell protoplasm can be recognised.

The blood-vessels of the sac wall are numerous and of very varying size. A striking feature is the number of dilated vessels with very thin walls which are seen, particularly in the middle layer of the sac-wall (fig. 3). Occasionally, but far less frequently, a small vessel can be recognised the lumen of which is narrowed. The contents of the vessels consist usually of red blood-cells, not differing in aspect from those seen in the cavity of the sac in immediate contact with its inner surface. Mixed with the red cells in the blood-vessels are a small number of mononucleated and multinucleated leucocytes. In addition, however, and particularly in the neighbourhood of the more abundant cell infiltration, cells, usually mononucleated, of large size, with abundant cell protoplasm, closely resembling those outside the vessels, are encountered in the blood contained in the blood-vessels of the sac-wall.

The cells lying in the meshes of the connective tissue of the sac-wall are free or loosely adherent to the connective tissue bundles or to each other. Occasionally they are arranged in rows of two to four (figs. 4 and 5), but more frequently are seen in the section to be more or less

isolated. Some of the cells are of small size, and possess little cytoplasm; this is especially the case near the inner surface (fig. 3). Others are of considerable size, reaching 40 μ or 50 μ in diameter. The increase in size generally affects the nucleus, but is chiefly caused by the abundance of cell-protoplasm (figs. 4 and 5). The cytoplasm is somewhat granular in aspect, and in some, but not all, of the cells contains masses of brownish-yellow pigmented material, which is tinted by protoplasmic stains and but little affected by nuclear dyes. This pigment is always arranged in little masses, and never appears diffused through the cell-protoplasm. It is clearly derived from red blood-cells, the remains of former hæmorrhages, and the cells in which it is found are macrophages. The amount of pigment which the cells contain varies considerably. It is absent from the smallest cells, and is generally most abundant in the largest cells, in which the nucleus stains badly, or may be unrecognisable (fig. 5). Nevertheless, some of the largest cells which the sac-wall exhibits may be quite free from pigment masses (fig. 4). Pigmented cells are found of large size and in large numbers in the middle of the sac-wall, but they are also present elsewhere, and can be recognised in the blood clot lying in immediate contact with the inner surface of the sac. The nuclei of the cells lying in the meshes of the connective tissue of the sac-wall are usually single and more or less rounded or oval in shape. Sometimes the nuclei are irregular in shape, and occasionally mononucleated cells, generally of small size, are seen.

Immediately in contact with the inner surface of the sac blood clot is found. This is little altered in aspect from that seen in the dilated vessels of the sac-wall. The red blood-cells preserve their form well. Penetrating for a distance of one-eighth to nearly one-half a millimetre, delicate blood capillaries are seen in the blood clot (fig. 3). These are accompanied by free cells. Beyond this distance few nuclei can be seen, but some ill-defined band-like structures are visible, the nature of which is not clear (fig. 3). No hæmatoidin crystals can be found near the inner surface of the sac-wall. In the central parts of the sac-cavity the solid or

semi-solid material present cannot be satisfactorily sectioned in thin layers. Sometimes connective tissue strands are recognisable, extending into the clot, but they are not abundant.

No bacteria could be recognised in the sac-wall or blood clot lying on its inner surface, on staining by Loeffler's, Gram's, or Ziehl-Neelson's methods. The pia arachnoid membrane, similarly examined, exhibited no bacteria.

The pia arachnoid was found to present an excess of connective tissue, the strands of which were coarse and contained numerous blood-vessels, together with an abundance of cells, usually mononucleated and containing a fairly large amount of cell-protoplasm, the largest being 20 μ to 25 μ in diameter.

The cerebral cortex exhibited some thickening of many of the blood-vessels contained in the gray matter. There was no marked increase in the neuroglial nuclei. The nerve-cells in the gray matter of the motor area did not appear much altered in aspect by v. Gieson's stain. Minute examination by Nissl's method could not be made, owing to the method of hardening adopted.

The optic nerves, stained by Marchi's method, gave evidence of degeneration, not intense in degree (fig. 6). There appeared to be some thickening of the connective tissue septa and nuclei of these nerves.

The spinal cord showed, by Marchi's method, some degeneration in the crossed pyramidal tracts, especially on the left side. By Pal's method also the spinal cord exhibited slight, but distinct, sclerosis of the crossed pyramidal tracts and also in the posterior columns.

Remarks upon the Preceding Observations.

The following points in connection with this pathological condition are worthy of note.

As already stated, two morbid processes are present within the skull cavity; the brain exhibits an atrophied wasted condition, with opacity of the pia arachnoid and fluid distension of the subarachnoid space and ventricles,

such as is so commonly found in asylum patients advanced in life, suffering from dementia; and in addition there is a subdural formation of large size, assuming the form of a cyst with well-formed wall and partly fluid contents. There is, therefore, a difficulty in the way of deciding how far the clinical symptoms which the patient presented should be attributed to the former and how far to the latter condition. The left-sided weakness and the degeneration of the crossed pyramidal tracts in the cord, chiefly on the left side, appear to be almost the only symptom and change which can with certainty be attributed to the subdural cyst. Previous to his removal to the workhouse infirmary, and also during his stay in the asylum, patient did not suffer from vomiting, nor did head pain appear to be, at any rate, an obtrusive symptom. There was, however, degeneration in the optic nerves, not marked in degree, so that optic neuritis must have been present during life.

The morbid process taking place in the subdural space is the condition of hæmorrhagic pachymeningitis, complicated by the occurrence of an unusual amount of hæmorrhage. The blood poured out has become encapsuled by the formation of fibroid tissue, both on its dural and on its pial aspect. At the edges the sac-wall becomes continuous with the rusty pellicle found elsewhere on the inner surface of the dura. That the process is of old standing is shown by the large amount of connective tissue which the wall of the sac contains. It is probable also, from the richness of the sac-wall in large-walled blood-vessels and from the abundance of cells which it contains, that the morbid process is progressive, and therefore it is likely that the effused blood which subsequently became encysted was not poured out on a single occasion, but was the result of several successive hæmorrhages.

In its microscopical characters the cyst-wall resembles the subdural membranes ordinarily met with, consisting as it does of a connective tissue framework containing numerous cells in its meshes together with very many large thin-walled blood-vessels. The cells, however, are much larger in size than those usually seen in the blood-stained membranes

lying on the inner surface of the dura mater, and the existence among them of macrophages in larger numbers than is generally the case in the latter is a striking feature. On the inner surface of the sac-wall the penetration of the blood clot lying within the cyst cavity by newly-formed capillaries accompanied by free cells is also beautifully seen. Connective tissue is later in its appearance in the blood clot than is the formation of new capillaries.

The formation of a blood cyst in the subdural space is a comparatively rare complication of hæmorrhagic internal pachymeningitis, though flattened hæmorrhages, not surrounded by a defined fibroid wall, are not rarely met with when subdural membranes are present, and may have a diameter of several centimetres.

The condition of the cerebrum is, by itself and apart from the distortion caused by the pressure of the blood cyst, indistinguishable, as already indicated, from that present in the brains of senile dements. Nevertheless, the extreme effusion of blood in the subdural space must be considered to have had a share in the production of the brain atrophy. How great this share is cannot, however, be gauged.

Both morbid conditions are very advanced. It has already been mentioned that the sac weighed 115 grs., while the weight of the entire brain was 1,045 grs. Nevertheless, the whole of the skull cavity was not occupied by brain and cyst together, room being still left for fluid in the subarachnoid space and ventricles.

DESCRIPTION OF THE ILLUSTRATIONS.

Fig. 1.

The brain seen from above, the subdural sac lying upon the right hemisphere having been removed. The sketch, made after hardening, shows the displacement of both hemispheres caused by the sac. The great longitudinal fissure is pressed over to the left of the mesial plane, especially in the middle of its course, being thus concave to the right. The right hemisphere is considerably flattened. The sulci are widened on the left side, but on the right, owing to the flatness of the surface, they are less distinct and assume a somewhat linear character.

R.R.; fissure of Rolando. *S.S.*; right Sylvian fissure (posterior limb). Three-quarters of the natural size.

FIG. 2.

Frontal section of brain and subdural cyst, made between the optic chiasma and the corpora mammillaria. To the right is seen the cyst lying flattened out upon the right hemisphere. Its wall is of fairly uniform thickness of one millimetre or a little less except at the edge of the cyst, where its right and left portions meet, and where its thickness is much increased. In this situation the sac-wall becomes continuous with a thin rusty pellicle lying adherent to the inner surface of the dura mater beyond the limits of the cyst. The cyst contents are partly solid, having in places an imperfectly stratified character, and in part consist of fluid containing particulate matter evidently derived from effused blood.

Both hemispheres are distorted in shape, the longitudinal fissure and corpus callosum being displaced to the left. The islands of Reil and the basal ganglia are altered in outline as shown in the figure. Both lateral ventricles and also the third ventricle are seen to be slightly dilated, as is also the anterior extremity of the right inferior cornu, which passes more forward than its fellow, and is therefore seen in the section. The subarachnoid space is distended with fluid, and the sulci are widened. Below the third ventricle a portion of the tuber cinereum is seen, and on each side are the optic tracts. On either side of the third ventricle is seen the corresponding optic thalamus, external to which lie the lenticular nuclei, each showing several divisions. Still more externally lie the outer capsules and the claustra, opposite which are the islands of Reil, and the posterior divisions of the fissures of Sylvius. Between the lenticular and caudate nuclei on each side is seen the internal capsule, above which is seen the tail of the caudate nucleus. Below each globus pallidus is seen the nucleus amygdalæ.

R.R.; fissure of Rolando. On the right side portions of this fissure are cut across in three places. Three-quarters of the natural size.

FIG. 3.

Section of the wall of the blood cyst, together with a portion of the contents lying in contact with its inner surface. The cyst-wall is made up of stout connective tissue bundles, well supplied with blood-vessels, which towards the upper part are of large calibre and thin walled (their contents have dropped out during the preparation of the section). Between the strands of connective tissue are cells of various kinds, especially numerous in the middle of the cyst-wall and at its inner surface. In the former situation the cells are frequently of large size, sometimes deeply staining, sometimes staining faintly, and not unfrequently loaded with brownish-yellow pigment. Towards the inner surface the cells generally are of small size. In all parts of the sac-wall elongated nuclei are recognisable, not surrounded by well-stained protoplasm, lying upon the connective tissue strands. In the blood clot, in contact with the inner surface of the cyst-wall, numerous capillaries can be recognised together with free cells. Deeper down the number of nuclei recognisable is considerably diminished. Some ill-defined band-like structures are also seen in the blood clot, the nature of which is not clear.

Stained with methylene blue. × 80.

FIG. 4.

Portion of wall of subdural cyst. The sketch shows an abundance of connective tissue strands, more or less wavy when cut longitudinally, in the meshes of which a number of cells showing much granular protoplasm are seen. Generally these cells are quite free; less frequently several cells are found in contact with each other, forming a string of two to four cells. Two of the cells contain pigment masses, but with this exception the cells are free from pigment. (In other situations the same section shows large numbers of cells with pigment, as in the next figure.)

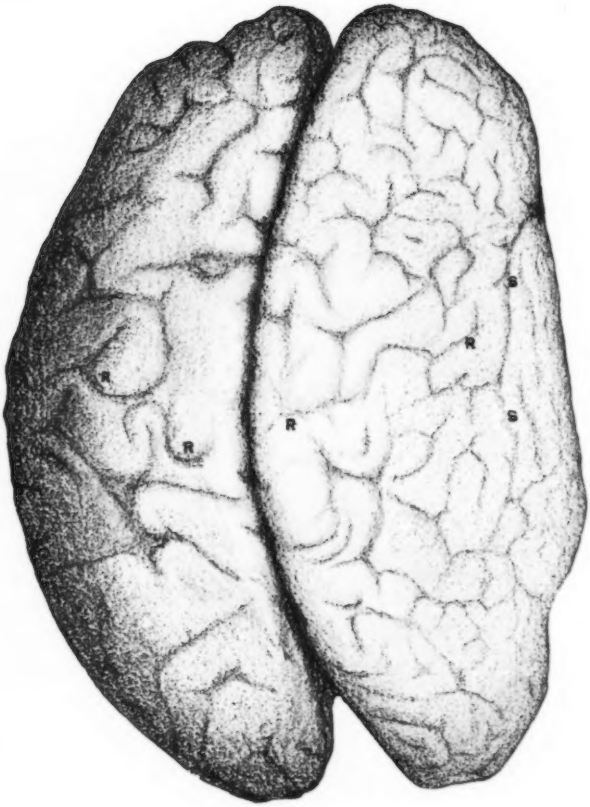
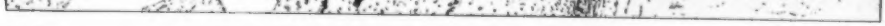


Fig. 1.

Fig. 2.



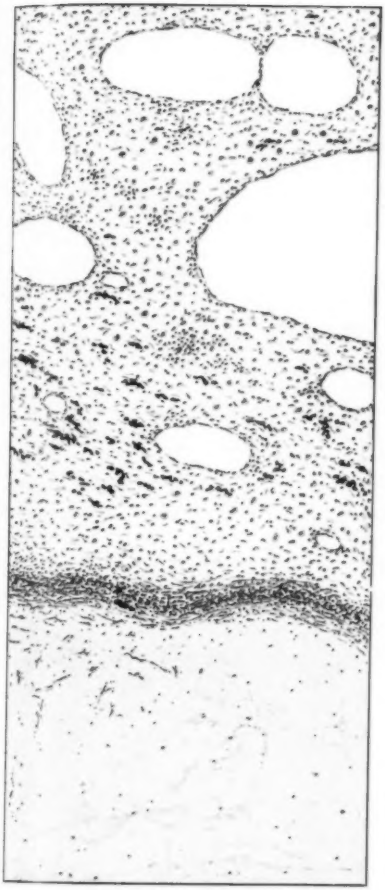


FIG. 3.

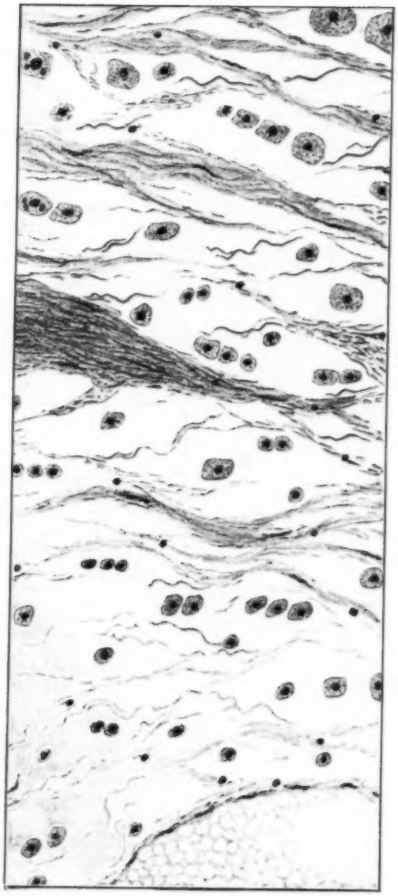


FIG. 4.

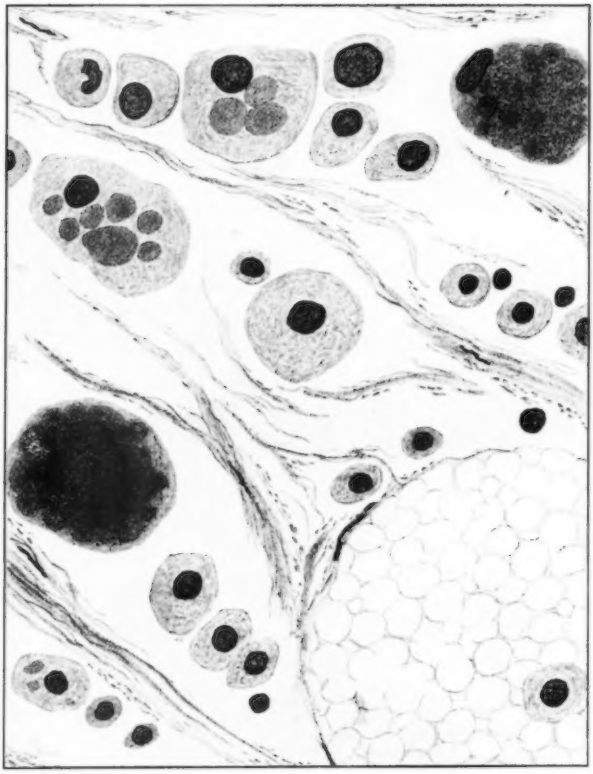


FIG. 5.

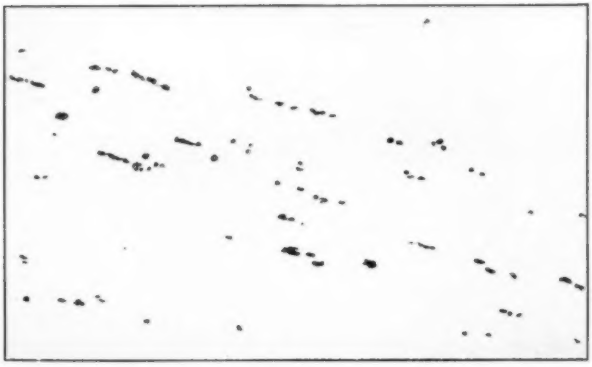


FIG. 6.

In addition, flattened elongated nuclei are seen in small numbers lying against the collagen strands.

In the lower part of the section part of a blood-vessel is seen.

v. Gieson's stain. × 200.

FIG. 5.

Wall of subdural cyst more highly magnified than in the preceding figure. The section exhibits a number of large cells (macrophages), the cytoplasm of which contains masses of pigment of varying size, of a yellowish-brown or yellowish-red colour. Where the pigment is very abundant the nucleus ceases to be recognisable. Some of the cells, especially those of small size, are free from pigment. Transitional forms are also seen. It will be noted that the nuclei of the smaller cells are smaller than those of the larger, but the difference between the two depends essentially upon the amount of cytoplasm, which is disproportionately greater in the large than in the small cells. The cell-protoplasm when free from pigmented material is of a finely granular aspect, and stains brown. No matter how abundant the pigmented material is, it remains in the form of small masses and does not become diffused through the cell-protoplasm.

Connective tissue strands are seen, cut across longitudinally, obliquely and transversely. Applied to these are seen in profile elongated flattened nuclei. In the lower right hand corner is seen a blood-vessel cut across transversely.

v. Gieson's stain. × 550.

FIG. 6.

The right optic nerve stained with osmic acid. A small amount of fatty *débris* is seen, the black particles being arranged parallel to the direction of the nerve-fibres.

× 250.

PROCEEDINGS OF THE NEUROLOGICAL SOCIETY OF LONDON.

Physiological Laboratory, St. Mary's Hospital, October 25, 1900.

Abstract of Dr. A. D. Waller's communication,

"ON THE EXCITABILITY OF NERVOUS MATTER: ITS LAST SIGN OF LIFE."

References to previous papers:—

No. 1.—"On the Excitability of Nervous Matter, with especial Reference to the Retina."—BRAIN, 1900, p. 1.

No. 2.—"On the Retinal Currents of the Frog's Eye, excited by light and excited electrically."—*Phil. Trans. R. S.*, 1900, March 29.

No. 3*a*.—"The Electrical Effects of Light upon Green Leaves."—*Proceedings R. S.*, 1900, June 6.

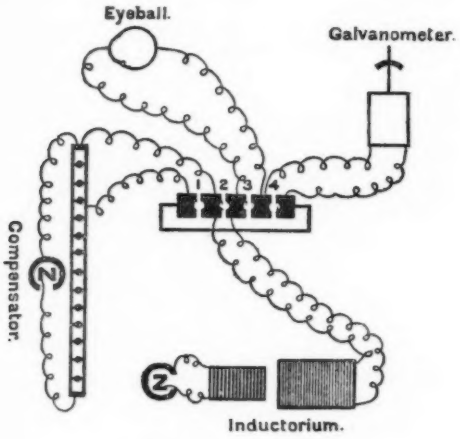
No. 3*b*.—"Four Observations concerning the Electrical Effects of Light upon Green Leaves."—*Proceedings Physiological Soc.*, 1900, June 30.

No. 4.—"Le Dernier Signe de Vie."—*C. R. Acad. des Sciences*, 1900, September 3.

In a previous communication (No. 1) to the Society, a summary description of the electrical effects of light upon the eye was given; evidence was offered of their duplex nature, and their modifications were systematically considered.

The whole subject is more fully studied and described in No. 2, which contains at p. 32 the first mention of a phenomenon that I have designated as the "retinal blaze."

First experiment. (Demonstration on eyeball.)



PLAN OF APPARATUS.

This "retinal blaze" is a large electrical after-effect of a single electrical stimulus, and *in the same direction as that stimulus.*

Its modifications with physiological modifications of the eye. Its disappearance at death.

Sensitiveness to light is a chief property of the retina (and skin) of animals and of the green leaves of plants. Electrical effects provoked by illumination of green leaves were therefore sought for and studied. A preliminary account of the results is contained in papers Nos. 3*a* and 3*b*. An electrical response to light is witnessed only in the case of actively-living green leaves; it is absent from other vegetable tissues (coloured petals, fruits, seeds, &c.).

The electrical response of a green leaf to illumination is one of its signs of life. A petal or a seed does not exhibit this sign, and we must have recourse to some other test by which to distinguish whether it is alive or dead.

Such a test is afforded by a reaction similar in principle to that of "retinal blaze." The reaction is of a most general character, and indicates whether an organ or tissue, animal or vegetable, is living or non-living. It is the last sign of life (No. 4).

Second experiment. (Demonstration: Living *versus* dead nerve.)

Third experiment. (Demonstration: Living *versus* dead egg.)

Probable nature of the phenomenon. A post-anodic action current.

Mr. Victor Horsley—

(1) A lantern demonstration on the course of the fillet fibres in the cat.

(2) A communication with reference to the cat shown at a previous meeting in which Brown-Sequard fits had been obtained after a lesion of the medulla. Since that meeting Mr. Horsley had completely divided the mesencephalon, and the fits could still be obtained. The cat had been killed and photographs were shown to demonstrate that, except for a trivial involvement of the cerebellum, the initial lesion was confined to the medulla, and that in the second experiment the division of the mesencephalon had been complete.